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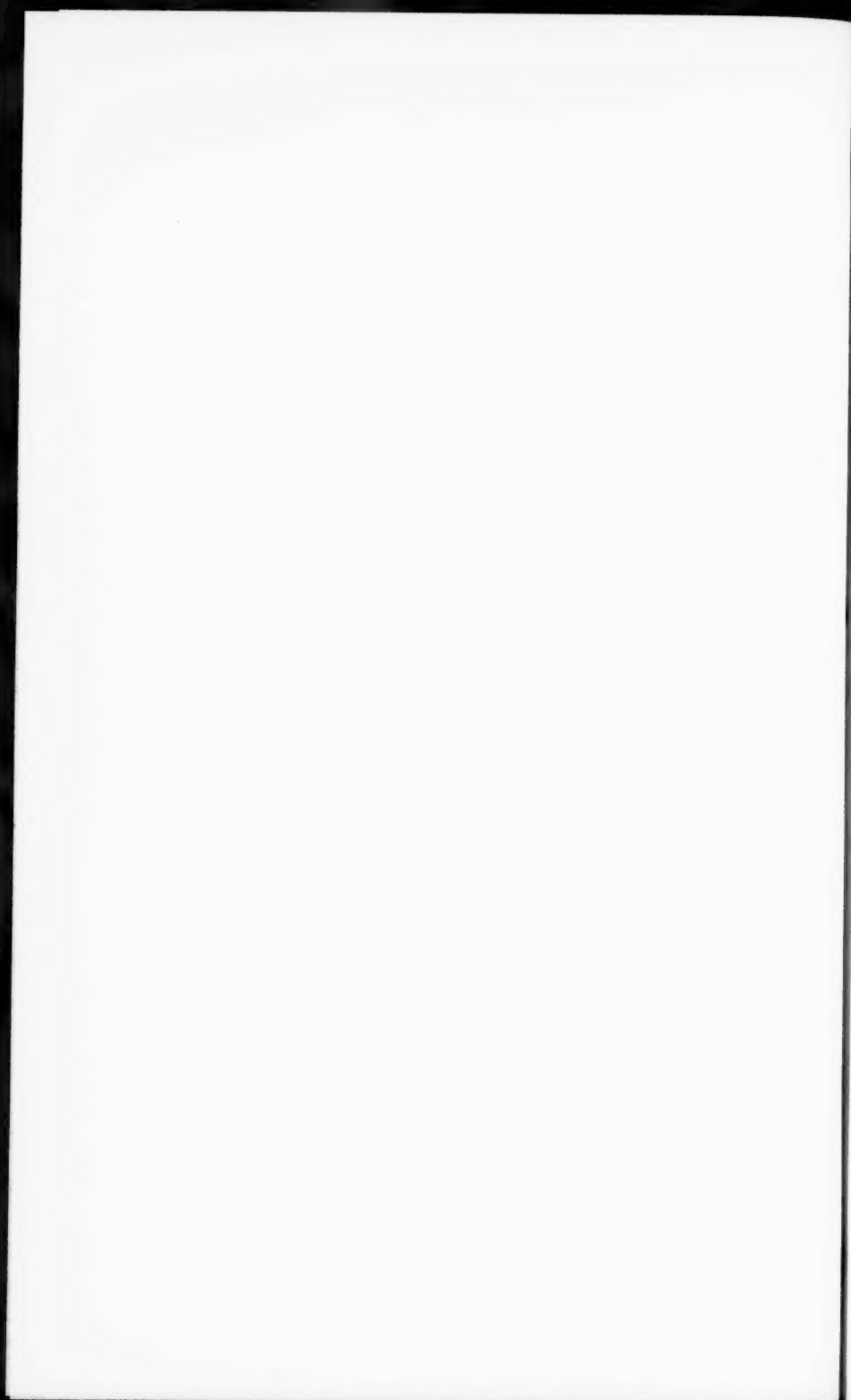
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ON INTEGRATING FACTORS AND JACOBI'S EQUATION.

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§ 1. The tentative nature of the search for suitable integrating factors usually perplexes the student of differential equations; he sees little point in the customary procedure of determining the condition that a differential $Pdx+Qdy$ should admit an integrating factor of a specified type when his main purpose is to search for an integrating factor of unknown type for a specified differential.

The method of the "common integrating factor" briefly described by the writer last year* seems to offer possibilities of systematic procedure; and the purpose of the present paper is to show how an application of the method to Jacobi's differential equation yields a complete solution in a form which renders comparatively easy a discussion of its singularities.

§ 2. The method is designed to apply to equations of the type

$$(P_1+P_2)dx+(Q_1+Q_2)dy=0 \quad (1)$$

and depends upon the possibility of determining a common integrating factor for the two differentials

$$P_1dx+Q_1dy \quad \text{and} \quad P_2dx+Q_2dy.$$

If μ be such a factor, and λ its logarithm, then

$$\frac{\partial \lambda}{\partial x} = \frac{\Delta_P}{\Delta} \quad \text{and} \quad \frac{\partial \lambda}{\partial y} = \frac{\Delta_Q}{\Delta} \quad (2)$$

where

$$\Delta = \begin{vmatrix} P_1 & Q_1 \\ P_2 & Q_2 \end{vmatrix} \neq 0$$

$$\Delta_P = \begin{vmatrix} P_1 & D_1 \\ P_2 & D_2 \end{vmatrix}; \quad \Delta_Q = \begin{vmatrix} Q_1 & D_1 \\ Q_2 & D_2 \end{vmatrix}$$

and

$$D_i = \frac{\partial P_i}{\partial y} - \frac{\partial Q_i}{\partial x} \quad (i=1, 2).$$

* J. P. Dalton, Amer. Math. Monthly, vol. xxxv, p. 189 (1928).
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Subject to the usual continuity conditions, therefore, a necessary condition for the existence of μ is that

$$\frac{\partial}{\partial y} \left(\frac{\Delta_P}{\Delta} \right) = \frac{\partial}{\partial x} \left(\frac{\Delta_Q}{\Delta} \right) \quad (3)$$

That (3) is also sufficient is evident from the following considerations. On account of (3) the differential

$$\left(\frac{\Delta_P}{\Delta} \right) dx + \left(\frac{\Delta_Q}{\Delta} \right) dy$$

is exact. Hence there exists some function $\lambda(x, y)$ such that

$$\frac{\partial \lambda}{\partial x} = \frac{\Delta_P}{\Delta} \quad \text{and} \quad \frac{\partial \lambda}{\partial y} = \frac{\Delta_Q}{\Delta}.$$

We have also, identically,

$$\frac{Q_i}{D_i} \cdot \frac{\Delta_P}{\Delta} - \frac{P_i}{D_i} \cdot \frac{\Delta_Q}{\Delta} = 1 \quad (i=1, 2) \quad (4)$$

Writing $\mu = e^\lambda$ we obtain

$$Q_i \frac{\partial \mu}{\partial x} - P_i \frac{\partial \mu}{\partial y} = \mu D_i \quad (5)$$

or

$$\frac{\partial}{\partial y} (\mu P_i) = \frac{\partial}{\partial x} (\mu Q_i),$$

which establishes the sufficiency of the criterion.

§ 3. Jacobi's equation *

$$(L_c - yL_a)dx = (L_b - xL_a)dy \quad (6)$$

where

$$L_r = r_1 + r_2x + r_3y \quad (r=a, b, c) \quad (7)$$

is of importance in the theory of linear transformations.† Writing

$$\begin{aligned} P_1 &= c_1 + c_2x + (c_3 - a_1)y; & Q_1 &= -b_1 - (b_2 - a_1)x - b_3y; \\ P_2 &= -y(a_2x + a_3y); & Q_2 &= x(a_2x + a_3y); \end{aligned}$$

criterion (3) leads to the conditions

$$\begin{aligned} c_1(a_1 - 2b_2 + c_3) + 3b_1c_2 &= 0 \\ b_1(a_1 + b_2 - 2c_3) + 3c_1b_3 &= 0. \end{aligned}$$

* Jacobi, Ges. Werke, 4, p. 256.

† Cf. e.g. Bateman, Diff. Eqns., p. 83 (1918).

These equations are not in general satisfied, but they suggest a suitable translation of the origin. By substituting

$$x = X + \xi; \quad y = Y + \eta \quad (8)$$

where ξ, η satisfy the equations

$$\begin{aligned} c_1 + c_2\xi + c_3\eta &= \eta(a_1 + a_2\xi + a_3\eta) \\ b_1 + b_2\xi + b_3\eta &= \xi(a_1 + a_2\xi + a_3\eta) \end{aligned}$$

equation (6) becomes

$$dX[kX + lY - Y(a_2X + a_3Y)] + dY[mX + nY + X(a_2X + a_3Y)] = 0 \quad (9)$$

where

$$\begin{aligned} k &= c_2 - a_2\eta; & l &= c_3 - a_1 - a_2\xi - 2a_3\eta \\ m &= a_1 - b_2 + 2a_2\xi + a_3\eta; & n &= -b_3 + a_3\xi \end{aligned} \quad (10)$$

Criterion (3) is satisfied by equation (9), and, consequently, integrating factors may be found.

The points (ξ, η) are the intersections of the conics

$$L_c = yL_a; \quad L_b = xL_a \quad (11)$$

which we shall call the fundamental conics. They are in general two hyperbolas, with one pair of asymptotes parallel to the line $L_a = 0$ and the other pair mutually perpendicular, and individually parallel to the x - and y -axis respectively. The former cuts the integral curves at points where their tangents are horizontal, and the latter at points where their tangents are vertical.

The fundamental conics intersect in general in three finite points ξ_i, η_i ($i=1, 2, 3$), and these points are the fixed singularities of the differential equation (6). For each singularity there are corresponding values of k, l, m , and n , and these quantities are related to the singular points inasmuch as the slopes of the fundamental conics at their intersections are

respectively $-\frac{k_i}{l_i}$ and $-\frac{m_i}{n_i}$.

Taking the transformed equation (9) and writing

$$\begin{aligned} P_1 &= kX + lY; & Q_1 &= mX + nY \\ P_2 &= -Y(a_2X + a_3Y); & Q_2 &= X(a_2X + a_3Y) \end{aligned}$$

we obtain

$$\begin{aligned} \frac{\partial \lambda}{\partial x} &= \frac{\Delta_P}{\Delta} = -\frac{3kX + (2l + m)Y}{kX^2 + (l + m)XY + nY^2} \\ \frac{\partial \lambda}{\partial y} &= \frac{\Delta_Q}{\Delta} = -\frac{(2m + l)X + 3nY}{kX^2 + (l + m)XY + nY^2} \end{aligned} \quad (12)$$

whence, on rejecting superfluous constants,

$$\lambda = \frac{l-m-3R}{2R} \log \{2kX + (l+m+R)Y\} - \frac{l-m+3R}{2R} \log \{2kX + (l+m-R)Y\} \quad (13)$$

where

$$R^2 = (l+m)^2 - 4nk \quad (14)$$

In terms of the original co-ordinates, therefore, we have the three integrating factors

$$\lambda_i = \left(\frac{l-m-3R}{2R} \right)_i \log [2k_i(x-\xi_i) + (l+m+R)_i(y-\eta_i)] - \left(\frac{l-m+3R}{2R} \right)_i \log [2k_i(x-\xi_i) + (l+m-R)_i(y-\eta_i)] \quad (i=1, 2, 3) \quad (15)$$

§ 4. Both for computation and for interpretation parametric representation is helpful. Let

$$\theta_i = a_1 + a_2\xi_i + a_3\eta_i \quad (i=1, 2, 3) \quad (16)$$

$$\Delta_1 = \begin{vmatrix} a_1 & a_2 & a_3 \\ b_1 & b_2 & b_3 \\ c_1 & c_2 & c_3 \end{vmatrix} \quad (17)$$

with corresponding co-factors A_1, B_1 , etc. Also let

$$s = a_1 + b_2 + c_3 \quad (18)$$

$$S = A_1 + B_2 + C_3 \quad (19)$$

The θ 's of (16) are then the roots of the characteristic cubic

$$\theta^3 - s\theta^2 + S\theta - \Delta_1 = 0 \quad (20)$$

and the intersections of the fundamental conics are

$$\left. \begin{aligned} \xi_i &= \frac{C_2 + b_3\theta_i}{C_1 + a_3\theta_i} \\ \eta_i &= \frac{B_3 + c_2\theta_i}{B_1 + a_2\theta_i} \end{aligned} \right\} \quad (21)$$

Furthermore, from (10) and (14),

$$\left. \begin{aligned} l_i - m_i - 3R_i &= -2[R_i - R_{i+1}] \\ l_i - m_i + 3R_i &= -2[R_{i+2} - R_i] \\ R_i &= \theta_{i+1} - \theta_{i+2}^* \end{aligned} \right\} \quad (22)$$

* In the case of different roots θ , these are assumed to be arranged in descending order; hence two R 's are positive and one is negative.

and if, for brevity, we write

$$M_i = l_i + m_i + R_i; \quad N_i = l_i + m_i - R_i$$

we obtain

$$\frac{2k_i}{M_i} = \frac{M_{i+2}}{2m_{i+2}} = \frac{2k_{i+2}}{N_{i+2}} = \frac{B_1 + a_2\theta_{i+1}}{C_1 + a_3\theta_{i+1}} = -\frac{\eta_{i+2} - \eta_i}{\xi_{i+2} - \xi_i} = -a_{i+1} \quad (23)$$

where the a 's are the slopes of the joins of the singular points.

From (23) it follows that the six linear functions whose logarithms appear in (15) reduce to three in number, and their vanishing gives the equations to the lines joining the singularities. If we label these linear functions l_i , then

$$l_i = y - \eta_{i+1} - a_i(x - \xi_{i+1}) \quad \text{or} \quad \begin{vmatrix} 1 & 1 & 1 \\ x & \xi_{i+1} & \xi_{i+2} \\ y & \eta_{i+1} & \eta_{i+2} \end{vmatrix} \quad \text{or} \quad \begin{vmatrix} L_a & 1 & 1 \\ L_b & \xi_{i+1} & \xi_{i+2} \\ L_c & \eta_{i+1} & \eta_{i+2} \end{vmatrix}^* \quad (24)$$

and the integrating factors (15) become

$$\lambda_i = \left(\frac{R_{i+1}}{R_i} - 1 \right) \log l_{i+1} + \left(\frac{R_{i+2}}{R_i} - 1 \right) \log l_{i+2} \quad (25)$$

Hence the solution of the differential equation (6) is, in general,

$$\sum_1^3 (\theta_{i+1} - \theta_{i+2}) \log l_i = \log C \quad (26)$$

§ 5. The discussion of the general solution (26) is facilitated by reference to certain lines.

The lines $l_i = 0$ joining the singular points are linear integrals of the differential equation. For along these lines, according to (24),

$$\begin{vmatrix} L_a & 1 & 1 \\ L_b - xL_a & \xi_{i+1} - x & \xi_{i+2} - x \\ L_c - yL_a & \eta_{i+1} - y & \eta_{i+2} - y \end{vmatrix} = 0,$$

whence

$$\frac{L_c - yL_a}{L_b - xL_a} = \frac{\eta_{i+2} - \eta_{i+1}}{\xi_{i+2} - \xi_{i+1}} = a_i.$$

The linear integrals accordingly form a triangle which may be termed the integral triangle; its vertices are the singularities of the equation, and the side opposite each vertex will be termed its associated linear integral.

There is also the group of three parallel lines, one through each singular point parallel to the common asymptotic direction of the fundamental hyperbolas. These lines will be called the parallel loci, as they intersect

* In the alternative forms certain coefficients are omitted.

the integral curves at points where these are parallel to each other and to the associated linear integral. For, with a singular point as origin,

$$\frac{dY}{dX} = -\frac{k_i X + l_i Y - Y(a_2 X + a_3 Y)}{m_i X + n_i Y + X(a_2 X + a_3 Y)}.$$

But along a parallel locus

$$a_2 X + a_3 Y = 0 \quad (27)$$

whence

$$\frac{dY}{dX} = -\frac{a_2 k_i - a_2 l_i}{a_3 m_i - a_2 n_i} = -\frac{B_1 + a_2 \theta_i}{C_1 + a_3 \theta_i} = \alpha_i \quad (28)$$

which establishes the property.

§ 6. If the roots of the characteristic cubic are real and distinct, so also are the singular points, the linear integrals, and the parallel loci. The three coefficients $\theta_{i+1} - \theta_{i+2}$ of (26) cannot all have the same sign; hence* two of the singularities are nodal points, and the other—namely, that point whose θ lies between the other two—is a saddle point.

Of the three parallel loci that which passes through the saddle point cuts the opposite side of the integral triangle internally, while those passing through the nodal points cut externally their opposite sides. For if \bar{x}_i refers to the intersection of the linear integral $l_i = 0$ with the parallel locus

$$a_3(y - \eta_i) + a_2(x - \xi_i) = 0 \quad (29)$$

then

$$\bar{x}_i = \xi_{i+1} + \frac{R_{i+2}}{a_2 + a_3 a_i} = \xi_{i+2} - \frac{R_{i+1}}{a_2 + a_3 a_i} \quad (30)$$

Hence

$$(\bar{x}_i - \xi_{i+1})(\bar{x}_i - \xi_{i+2}) = -\frac{(\theta_i - \theta_{i+1})(\theta_{i+2} - \theta_i)}{(a_2 + a_3 a_i)^2} \quad (31)$$

and this is negative for the saddle point, positive for the two nodal points.

Now consider lines drawn parallel to one of the linear integrals, say $l_i = g = \text{constant}$, and let C_g refer to values of the parameter of the integral curves where they are cut by these lines. Differentiating along them we get

$$\frac{\partial \log C_g}{\partial x} = \frac{R_{i+1}}{l_{i+1}}(a_i - a_{i+1}) + \frac{R_{i+2}}{l_{i+2}}(a_i - a_{i+2}) \quad (32)$$

Also

$$a_i - a_{i+1} = \frac{(a_3 B_1 - a_2 C_1) R_{i+2}}{(C_1 + a_3 \theta_i)(C_1 + a_3 \theta_{i+1})} \quad (33)$$

* Subject to the convention of § 4.

so that $\frac{\partial \log C_g}{\partial x}$ vanishes along the line (29), and nowhere else. Moreover, along this line

$$\frac{\partial^2 \log C_g}{\partial x^2} = R_i R_{i+1} R_{i+2} \left(\frac{a_{i+2} - a_i}{R_{i+1} l_{i+2}} \right)^2 \quad (34)$$

a quantity which is essentially negative. Hence, along any line parallel to a linear integral the parameter $\log C$ attains a unique maximum, and the locus of these maxima is the parallel locus through the associated singular point.

And if C_{P_i} refers to values of the parameter along the parallel locus through the singularity ξ_i , we have

$$\frac{\partial \log C_{P_i}}{\partial x} = \frac{R_i(\bar{x}_i - \xi_i)}{(x - \bar{x}_i)(x - \xi_i)} \quad (35)$$

This changes sign twice on each parallel locus. In the case of the saddle point $\log C_P$ increases from that point to the associated linear integral; in the case of the two nodal points it decreases under the same conditions, but in the opposite direction. It is also clear that along each parallel locus $\log C_{P_i}$ approaches a finite limit as $x \rightarrow \infty$.

Regard the plane as divided into four sectors by the linear integrals through the saddle point. The integral curves may be divided into two groups. The curves of one group occupy the sector which contains the integral triangle and the opposite sector; they pass through the two nodal points, being there tangent to the linear integrals joining those points with the saddle point, and they approach the latter point within the integral triangle. As long as $\log C$ does not reach its limiting value for the parallel locus through the saddle point, the integral curves are closed curves in the sector containing the integral triangle; but when $\log C$ transcends that value, the integral curves extend to infinity on the one side and return towards the saddle point in the opposite sector.

In the other pair of sectors the integral curves consist of open branches passing through the nodal points, approaching the saddle point, and then receding.

§ 7. A particular case of interest occurs when $a_3 B_1 = a_2 C_1$. The fundamental hyperbolas then have a common asymptote, and one of the singular points recedes to infinity. The θ of that point is $-\frac{B_1}{a_2} = -\frac{C_1}{a_3} = \bar{\theta}_i$. For each of the other roots

$$B_1 + a_2 \theta = a_2 (\theta - \bar{\theta}_i) \quad \text{and} \quad C_1 + a_3 \theta = a_3 (\theta - \bar{\theta}_i).$$

Hence

$$\alpha_{i+1} = \alpha_{i+2} = -\frac{\alpha_2}{\alpha_3} \quad (36)$$

so that these linear integrals are parallel to the common asymptote, and are identical with the corresponding parallel loci. Since from (32) and (36)

$$\frac{R_{i-1}}{L_a - \theta_{i-2}} + \frac{R_{i-2}}{L_a - \theta_{i-1}} = 0 \quad (37)$$

and therefore

$$L_a = \bar{\theta}_i \quad (38)$$

on the remaining parallel locus, it is itself the common asymptote of the two fundamental conics.

Since the three parallel loci are $L_a = \theta_i (i=1, 2, 3)$ it follows that if the singular point at infinity is a saddle point, then the common asymptote lies between the parallel linear integrals; while if it is a nodal point, the common asymptote lies outside the parallel linear integrals. As the common asymptote is also the parallel locus for the remaining linear integral, it follows that when $\bar{\theta}_i$ lies between the other two roots of (20) the integral curves consist of (i) a series of closed curves filling the strip between the parallel linear integrals and entering the nodal points tangent to those lines; and (ii) a series of hyperbolic type curves entering the nodal points from without the parallel strip and contracting from the one limiting position of the parallel linear integrals to that of the two external segments of the other linear integral.

If, however, $\bar{\theta}_i$ lie outside the interval between the other two roots, the singularity at infinity is nodal; and of the two finite singularities one is nodal and the other saddle, the latter being the singular point nearer to the common asymptote. The integral curves are now all hyperbolic in character. On the asymptote side of the parallel strip two groups are separated by the other linear integral; the curves move towards the saddle point, cross the common asymptote, being there parallel to the third linear integral, and move off again within the strip between the common asymptote and the nearer parallel linear integral. The other two groups are also separated by the join of the singular points. Their curves approach the saddle point within the parallel strip, turn, and pass out through the nodal point, being there touched by the join of the singularities.

§ 8. If two roots of the characteristic cubic are equal, two of the singularities coalesce, and the fundamental conics touch at that point. Two distinct linear integrals remain—the join of the singular points and the common tangent to the fundamental conics. There are also two distinct parallel loci. Since (§ 6) a central value of θ corresponds to a saddle point,

it follows that, when two roots coalesce, the resulting singularity is formed by the union of a nodal point with a saddle point, and must partake of the nature of each; the single singularity retains its nodal character.

The formal integral in this case could be obtained by a limiting process* from the general solution (26), but it seems more appropriate, as well as more convenient, to use the method of the common integrating factor.

Since $\theta_2 = \theta_3$ then $R_1 = 0$. Therefore

$$(l_1 + m_1)^2 = 4n_1k_1 \quad (39)$$

The integral of (12) in original co-ordinates accordingly becomes

$$\lambda_1 = -3 \log [2k_1(x - \xi_1) + (l_1 + m_1)(y - \eta_1)] + \frac{(l_1 - m_1)(y - \eta_1)}{2k_1(x - \xi_1) + (l_1 + m_1)(y - \eta_1)} \quad (40)$$

Furthermore, from (15) we have

$$\lambda_2 = -2 \log [2k_2(x - \xi_2) + M_2(y - \eta_2)] - \log [2k_2(x - \xi_2) + N_2(y - \eta_2)] \quad (41)$$

In view of the relations (23) and of the identity of the points 2 and 3, the join of the singularities is

$$2k_1(x - \xi_1) + (l_1 + m_1)(y - \eta_1) = 0 = 2k_2(x - \xi_2) + M_2(y - \eta_2) \quad (42)$$

while the common tangent to the fundamental conics is

$$2k_2(x - \xi_2) + N_2(y - \eta_2) = 0 \quad (43)$$

If we write

$$\left. \begin{aligned} a_1 &= \frac{\eta_2 - \eta_1}{\xi_2 - \xi_1} \\ a_2 &= -\frac{k_2}{l_2} = -\frac{m_2}{n_2} = -\frac{2k_2}{N_2} \end{aligned} \right\} \quad (44)$$

for the slopes of the linear integrals, and

$$\left. \begin{aligned} L &= y - \eta_1 - a_1(x - \xi_1) \\ T &= y - \eta_2 - a_2(x - \xi_2) \end{aligned} \right\} \quad (45)$$

we obtain for the integral curves

$$\log \frac{T}{L} + \frac{l_1 - m_1}{l_1 + m_1} \frac{y - \eta_1}{L} = \log C \quad (46)$$

As the integral triangle is no longer complete, the relations (35) giving the change of parameter along the parallel loci are no longer directly applicable. The conditions of contact of the fundamental conics show that a_1 is the unique root of

$$n_1 a^2 + (l_1 + m_1)a + k_1 = 0,$$

* As done by Serret, *Calc. Int.*, 6th ed. p. 431 (1911).

and that α_1 , and α_2 are the roots of

$$n_2 a^2 + (l_2 + m_2)a + k_2 = 0.$$

From these conditions we obtain

$$\left. \begin{aligned} k_1 + l_1 \alpha_1 &= -(k_2 + l_2 \alpha_1) = l_2(a_2 - \alpha_1) = (\eta_2 - \eta_1)(a_2 + a_3 \alpha_1) \\ m_1 + n_1 \alpha_1 &= -(m_2 + n_2 \alpha_1) = n_2(a_2 - \alpha_1) = -(\xi_2 - \xi_1)(a_2 + a_3 \alpha_1) \end{aligned} \right\} \quad (47)$$

whence

$$\frac{l_1 - m_1}{l_1 + m_1} = \frac{a_2 - \alpha_1}{\alpha_1} \cdot \frac{a_2 + a_3 \alpha_1}{a_2 + a_3 a_2} \quad (48)$$

The intersections of the parallel loci with the associated linear integrals are now reduced to one, and for it we obtain

$$\bar{x} - \xi_1 = \frac{a_3(a_1 - a_2)(\xi_1 - \xi_2)}{a_2 + a_3 a_2} \quad (49)$$

From (45), (46), and (49), and from the equations to the parallel loci, we find that along the parallel locus through the simple singularity

$$\frac{\partial \log C_{P_1}}{\partial x} = \frac{\bar{x} - \xi_1}{(x - \xi_1)(x - \bar{x})} \quad (50)$$

and along that through the double singularity

$$\frac{\partial \log C_{P_2}}{\partial x} = \frac{\bar{x} - \xi_1}{(x - \xi_2)^2} \quad (51)$$

The former changes sign twice, the latter not at all, as x moves along the respective parallel locus.

Consider the plane to be divided into four sectors by the two linear integrals. Let number I be that sector which has both singularities on its boundary and within which parts of both parallel loci lie; let II be the neighbouring sector which contains a portion of the parallel locus through the simple singularity; and let III and IV be the respective opposites of these sectors.

In sector I the integral curves leave the nodal point along the linear integral joining the two singularities, in the direction away from the second singularity. At first they turn inwards and return to the double singularity, entering it along the common tangent to the fundamental conics, thus forming a series of loops joining the singular points. When the limiting value of the parameter C is passed the loops are broken at infinity and the integral curves there pass into the opposite sector III, which is filled by a series of hyperbolic branches having the double singularity as their saddle point.

In sector II curves leave the nodal point along the linear integral passing through it towards the other singular point. At first they bend sharply back, proceeding to infinity in the opposite direction. As the parameter C alters, the integral curves widen and their summits approach more closely the double singularity, which is for them a saddle point. These curves return from infinity in the opposite sector IV, and, as this sector contains no part of either parallel locus, the integral curves in it move smoothly up to the double singularity, entering it as a nodal point along the common tangent.

The simple singularity, corresponding to the non-repeated root of the characteristic cubic, is therefore a nodal point; while the other singularity, corresponding to the repeated root, is a nodal point on one side of the join of the two singularities, and on the other side is a saddle point.

§ 9. When the characteristic cubic is a perfect cube equations (15) yield but one integrating factor, and an additional quadrature is required for the solution of the differential equation. In this case the fundamental conics osculate at the singular point; the three linear integrals unite in the common tangent; the three parallel loci also coalesce.

The triple root θ is $\frac{1}{3}(a_1 + b_2 + c_3)$; and in terms of the constants (10) the conditions of osculation may be written

$$l^2 = nk = lm \quad (52)$$

Hence

$$\frac{\Delta_P}{\Delta} = -\frac{3k}{kX + lY}; \quad \frac{\Delta_Q}{\Delta} = -\frac{3l}{kX + lY} \quad (53)$$

Thus

$$\lambda = -3 \log (kX + lY)$$

and therefore, in terms of original co-ordinates, the integral curves * are

$$2[k - a_2(y - \eta)]L + (a_2l - a_3k)(y - \eta)^2 = CL^2 \quad (54)$$

where

$$L = k(x - \xi) + l(y - \eta) \quad (55)$$

This is a family of conics of no particular interest. They all pass through the singular point (ξ, η) , which is a nodal point; at it they are tangent to the linear integral $L=0$, which is the common tangent to the fundamental conics. The parallel locus

$$a_2(x - \xi) + a_3(y - \eta) = 0$$

is the line of centres of the integral curves.

§ 10. When the characteristic cubic has two complex roots the fundamental conics intersect in only one real singularity. Let the subscript 1

* A result obtained by Serret, *op. cit.*, p. 432.

refer to this point, and let $\theta_{2,3} = \vartheta \pm i\phi$; $\xi_{2,3} = p \pm iq$; $\eta_{2,3} = u \pm iv$, so that in equation (26) the coefficient $\theta_2 - \theta_3$ is purely imaginary, and the other two coefficients are complex.

The line $l_1 = 0$ is then the real join of the complex intersections of the fundamental conics; it is the only real linear integral of the differential equation; it does not pass through the real singular point. There is also but one real parallel locus.

If we write, where (ξ, η) is the real singularity,

$$\left. \begin{aligned} L &= v(x-p) - q(y-u) \\ U &= (\eta-u)(x-p) - (\xi-p)(y-u) \\ V &= v(x-\xi) - q(y-\eta) \end{aligned} \right\} \quad (56)$$

then solution (26) becomes

$$\log \frac{L}{\sqrt{U^2 + V^2}} + \frac{\vartheta - \theta_1}{\phi} \arctan \frac{V}{U} = \log C \quad (57)$$

$L=0$ is the real linear integral; $V=0$ is the line parallel to L and passing through the real singularity, where it is cut by the line $U=0$.

From (57) it is evident that the integral curves consist of spirals having (ξ, η) as their asymptotic point. Their relation to the linear integral can be discussed by means of the parallel locus

$$a_2(x-\xi) + a_3(y-\eta) = 0.$$

Since

$$\left. \begin{aligned} \vartheta - \theta_1 &= -a_2(\xi-p) - a_3(\eta-u) \\ \phi &= a_2q + a_3v \end{aligned} \right\} \quad (58)$$

and

the parallel locus may be written

$$\phi U + (\vartheta - \theta_1)V = 0 \quad (59)$$

Hence, along the parallel locus, we obtain

$$\frac{\partial \log C_P}{\partial x} = \frac{\partial V_P}{\partial x} \left(\frac{1}{L} - \frac{1}{V} \right) = \frac{\bar{x} - \xi}{(x - \bar{x})(x - \xi)} \quad (60)$$

where \bar{x} is the point of cut of the parallel locus with the linear integral. On that portion of the parallel locus on which the singularity lies the curve parameter increases up to the singular point; it decreases between that point and the linear integral; it then increases monotonically. All convolutions of the spirals, therefore, cross the parallel locus between the focal point and the linear integral, becoming flatter as this line is approached. On the side of the focal point, remote from the linear integral, the integral

curves spread out, and on reaching infinity return on the opposite side of this line with their convolutions convex thereto.

§ 11. A particular case of (57) of obvious interest is when $\theta_1 = \vartheta$, i.e. when the real root is equal to the real part of the complex roots; for then the multiple-valued function disappears, and the solution is left as the family of conics

$$L^2 = C(U^2 + V^2) \quad (61)$$

From (59) the parallel locus is now $U=0$, and on it lie the centres of the conics (61). From (56) and (59) the point p, u is the intersection of the linear integral with the parallel locus.

Since L, U , and V cannot vanish simultaneously, and as (ξ, η) is the intersection of $U=0=V$, it follows that none of the integral curves pass through the singular point; it is therefore a central point.

Along the parallel locus

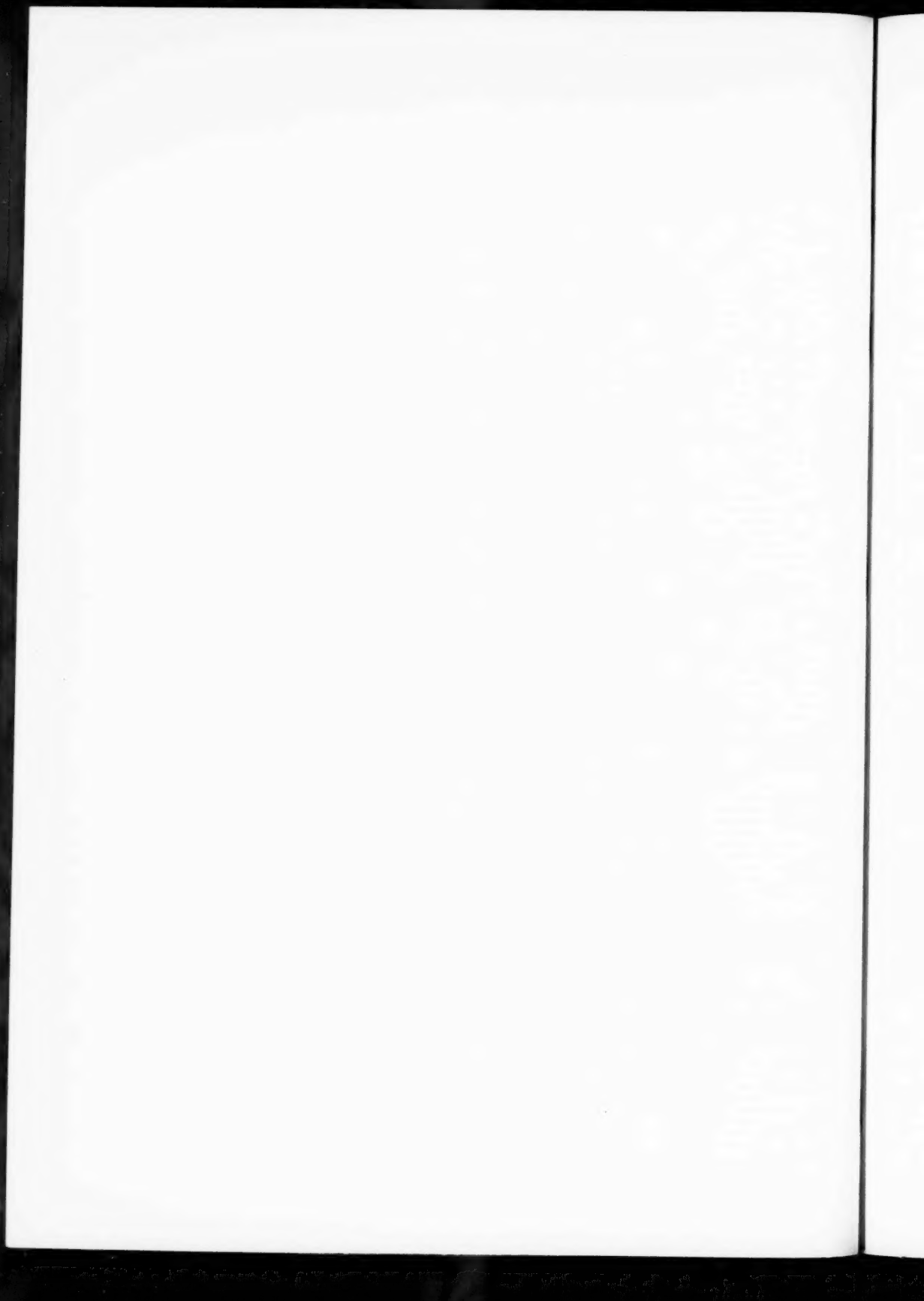
$$C_p = \left(\frac{x-p}{x-\xi} \right)^2,$$

therefore

$$\frac{\partial C_p}{\partial x} = -\frac{2}{(x-\xi)^2} \frac{(\xi-p)(x-p)}{(x-\xi)},$$

so that C_p increases up to the singular point, decreases to zero between it and the linear integral, and increases again on the other side of that line. The limiting value of C_p as $x \rightarrow \infty$ is unity. Hence for parameters lying between 0 and 1 the integral curves are ellipses encircling the singularity; for $C=1$ the integral curve is a parabola; for $C>1$ the integral curves are hyperbolas.

JOHANNESBURG,
21st June 1929.



NOTE ON MONGE'S RELATION BETWEEN PRIMARY
MINORS OF A 3-BY-5 ARRAY.

By Sir THOMAS MUIR, F.R.S.

1. The relation in question is

$$\begin{aligned}
 - \begin{vmatrix} a_1 & c_2 & d_3 \\ a_1 & b_2 & d_3 \\ b_1 & c_2 & e_3 \end{vmatrix} &- \begin{vmatrix} a_1 & b_2 & c_3 \\ b_1 & c_2 & d_3 \\ a_1 & d_2 & e_3 \end{vmatrix} \\
 &+ \begin{vmatrix} a_1 & c_2 & d_3 \\ a_1 & b_2 & c_3 \\ b_1 & d_2 & e_3 \end{vmatrix} \\
 &+ \begin{vmatrix} b_1 & c_2 & d_3 \\ a_1 & b_2 & d_3 \\ a_1 & c_2 & e_3 \end{vmatrix} = 0,
 \end{aligned}$$

the eight determinants involved in it being seen to be minors of the array

$$\begin{array}{ccccc}
 a_1 & b_1 & c_1 & d_1 & e_1 \\
 a_2 & b_2 & c_2 & d_2 & e_2 \\
 a_3 & b_3 & c_3 & d_3 & e_3.
 \end{array}$$

If we denote each determinant by the numbers of its columns in the array, the relation takes the more concise form

$$\begin{aligned}
 - \begin{vmatrix} 134 \\ 124 \\ 235 \end{vmatrix} &- \begin{vmatrix} 123 \\ 234 \\ 145 \end{vmatrix} \\
 &+ \begin{vmatrix} 134 \\ 123 \\ 245 \end{vmatrix} + \begin{vmatrix} 234 \\ 124 \\ 135 \end{vmatrix} = 0.
 \end{aligned}$$

It is the first-known instance of a *vanishing aggregate of ternary products of determinants*, and dates from the year 1809.* Strange to say, a hundred years had to elapse before any such aggregate came again to be referred to.

2. The fate of similar aggregates of *binary* products was very different. They were first dealt with by Bezout in 1779; and, save at the outset, they suffered no lengthy period of neglect: for, associated with them in history, one finds the names of Monge (1809), Cauchy (1812), Wronski (1816), Schweins (1825), Reiss (1829), and Sylvester (1839, 1851), the contributions of Schweins and Sylvester being specially noteworthy. Next they were considered sufficiently important for admission to a textbook, first by Brioschi in 1854 and then by Baltzer in 1856. In 1877 the advantage of viewing the aggregate as a development of a vanishing determinant was insisted on by Cayley; and as a consequence that line is taken throughout the eleven pages (pp. 121-133) devoted to the subject in my textbook of 1882, and also in the latest and still fuller and more comprehensive exposition given by Turnbull.†

* Journ. de l'École Polyt., viii, pp. 107-109; or Hist. of Det., i, pp. 67-68.

† Determinants, Matrices, and Invariants (Blackie & Son), 1928.

3. In view of this contrast it is interesting and probably not unprofitable to inquire what Monge's equality would have led to had it received similar attention to Bezout's, and more especially had it been found transformable into a single vanishing determinant.

4. Returning, then, to our four terms we observe that $|a_1 b_2 c_3|$ is a factor of two of them and $|a_1 b_2 d_3|$ a factor of the other two, the co-factors being

$$\begin{array}{l} |a_1 c_2 d_3| \quad |b_1 d_2 e_3| - |b_1 c_2 d_3| \quad |a_1 d_2 e_3|, \\ |a_1 c_2 e_3| \quad |b_1 c_2 d_3| - |a_1 c_2 d_3| \quad |b_1 c_2 e_3|. \end{array}$$

Now the former of these is readily seen to be expressible as the 6-line determinant

$$\begin{vmatrix} c_1 & d_1 & a_1 & b_1 & . & . \\ c_2 & d_2 & a_2 & b_2 & . & . \\ c_3 & d_3 & a_3 & b_3 & . & . \\ . & . & a_1 & b_1 & d_1 & e_1 \\ . & . & a_2 & b_2 & d_2 & e_2 \\ . & . & a_3 & b_3 & d_3 & e_3 \end{vmatrix}, \text{ or X say;}$$

and the latter being derivable from the former by the interchange of c 's and d 's must therefore be expressible as

$$\begin{vmatrix} d_1 & c_1 & a_1 & b_1 & . & . \\ d_2 & c_2 & a_2 & b_2 & . & . \\ d_3 & c_3 & a_3 & b_3 & . & . \\ . & . & a_1 & b_1 & c_1 & e_1 \\ . & . & a_2 & b_2 & c_2 & e_2 \\ . & . & a_3 & b_3 & c_3 & e_3 \end{vmatrix}, \text{ or Y say.}$$

Our next aim of course is to condense $|a_1 b_2 c_3|X - |a_1 b_2 d_3|Y$ in similar fashion: and with a little trial and testing it is soon attained, the final result being the obtaining of Monge's equality in the form

$$\begin{vmatrix} a_1 & b_1 & c_1 & d_1 & . & . & . & . & . \\ a_2 & b_2 & c_2 & d_2 & . & . & . & . & . \\ a_3 & b_3 & c_3 & d_3 & . & . & . & . & . \\ . & . & . & . & a_1 & b_1 & c_1 & d_1 & . \\ . & . & . & . & a_2 & b_2 & c_2 & d_2 & . \\ . & . & . & . & a_3 & b_3 & c_3 & d_3 & . \\ . & . & c_1 & d_1 & a_1 & b_1 & . & . & e_1 \\ . & . & c_2 & d_2 & a_2 & b_2 & . & . & e_2 \\ . & . & c_3 & d_3 & a_3 & b_3 & . & . & e_3 \end{vmatrix} = 0,$$

where, perhaps, the most conspicuous feature is the repetition of the 3-by-4 array.

5. With this before us generalisation is now an easy matter, and that in more directions than one. For example, we still obtain a vanishing aggregate when we introduce an entirely fresh 3-by-4 array, changing every a after the third row into h , every b into k , every c into f , and every d into g , the whole array of involved variables being 3-by-9, and the identity

$$0 = |123| \left\{ |567| |789| - |578| |679| + |579| |678| \right\} \\ - |124| \left\{ |567| |689| - |568| |679| - |569| |678| \right\}.$$

6. It is worth note in passing that the cofactor of $|123|$ here may be written

$$|567| |897| - |587| |697| + |597| |687|,$$

and being thus seen to be the extensional of

$$|56| |89| - |58| |69| + |59| |68|$$

is known from Bezout to vanish. The same is true of the cofactor of $|124|$: so that we have a verificatory proof of our result.

7. When we try to make a further advance in increasing the number of variables, it is of course found more difficult for the determinant to retain the property of providing a vanishing aggregate. We are, however, unexpectedly brought face to face with a quite different and more interesting property—the representation of a compound determinant. If the additional new letters introduced in the last three rows be p, q, r , the actual result is

$$\begin{vmatrix} a_1 & b_1 & c_1 & d_1 & . & . & . & . & . \\ a_2 & b_2 & c_2 & d_2 & . & . & . & . & . \\ a_3 & b_3 & c_3 & d_3 & . & . & . & . & . \\ . & . & . & . & h_1 & k_1 & f_1 & g_1 & . \\ . & . & . & . & h_2 & k_2 & f_2 & g_2 & . \\ . & . & . & . & h_3 & k_3 & f_3 & g_3 & . \\ p_1 & q_1 & r_1 & e_1 & p_1 & q_1 & r_1 & e_1 & e_1 \\ p_2 & q_2 & r_2 & e_2 & p_2 & q_2 & r_2 & e_2 & e_2 \\ p_3 & q_3 & r_3 & e_3 & p_3 & q_3 & r_3 & e_3 & e_3 \end{vmatrix} = \begin{vmatrix} |b_1 c_2 d_3| & |a_1 c_2 d_3| & |a_1 b_2 d_3| \\ |k_1 f_2 g_3| & |h_1 f_2 g_3| & |h_1 k_2 g_3| \\ |q_1 r_2 e_3| & |p_1 r_2 e_3| & |p_1 q_2 e_3| \end{vmatrix},$$

where each 3-by-4 array is seen to provide a row of the compound and to obey a fixed rule in doing so. It is analogous in type to that first reached by Whittaker in 1918* and extended by Krawtchouk in 1926.† The

* Proc. Edin. Math. Soc., xxxvi, pp. 107-115.

† L'Enseignement Math., xxv, pp. 72-74.

general theorem of which it is a case dates from 1919,* and may be very succinctly stated as follows:—

If A_1, A_2, \dots, A_{p+1} stand for arrays of m rows and $m+1$ columns, and A_{p+1}' stand for A_{p+1} with its first $p+1$ columns struck out, then

$$\begin{vmatrix} A_1 & . & . & . & . & . \\ . & A_2 & . & . & . & . \\ . & . & . & . & . & . \\ . & . & . & . & A_p & . \\ A_{p+1} & A_{p+1} & . & . & A_{p+1}' & A_{p+1}' \end{vmatrix} = | A_{11} A_{22} \dots A_{p+1, p+1} |,$$

where A_{rs} is the determinant whose array is got from A_r by removing its s^{th} column.

In the above example the m of this is 3 and the p is 2.

RONDEBOSCH, S.A.,
7th July 1929.

P.S.—A year ago in a paper published on pp. 121–124 of the preceding volume I drew attention to an application of the following theorem in matrices: If (P) and (Q) be the matrices of any two determinants of the n^{th} order, the $2n$ -line determinant

$$\begin{vmatrix} (P) & (Q) \\ (Q) & (P) \end{vmatrix}$$

is expressible as the product of two determinants of the n^{th} order

$$| (P) + (Q) | \quad \text{and} \quad | (P) - (Q) |,$$

in close analogy with the simple equality

$$\begin{vmatrix} p & q \\ q & p \end{vmatrix} = (p+q)(p-q).$$

Unfortunately, through forgetfulness I neglected to refer to a specially interesting case of the theorem, namely, the case where (P) is axisymmetric and (Q) is zero-axial skew. In that case the matrices $(P) + (Q)$ and $(P) - (Q)$ only differ in the one being the conjugate of the other, and their determinants are therefore equal, and the product a square. For example,

$$\begin{vmatrix} a & h & g & . & z & y \\ h & b & f & -z & . & x \\ g & f & c & -y & -x & . \\ . & z & y & a & h & g \\ -z & . & x & h & b & f \\ -y & -x & . & g & f & c \end{vmatrix} = \begin{vmatrix} a & h+z & g+y \\ h-z & b & f+x \\ g-y & f-x & c \end{vmatrix}^2.$$

* Quart. Journ. of Math., xlviii, pp. 379–384.

If for (P) and (Q) as thus specialised we write (A) and (S), what we have got is

$$\begin{vmatrix} (A) & (S) \\ (S) & (A) \end{vmatrix} = |(A)+(S)|^2;$$

and if, further, in this we write $i(S)$ for (S) we can establish the fact that the square of a hermitant is expressible as a determinant with rational elements.

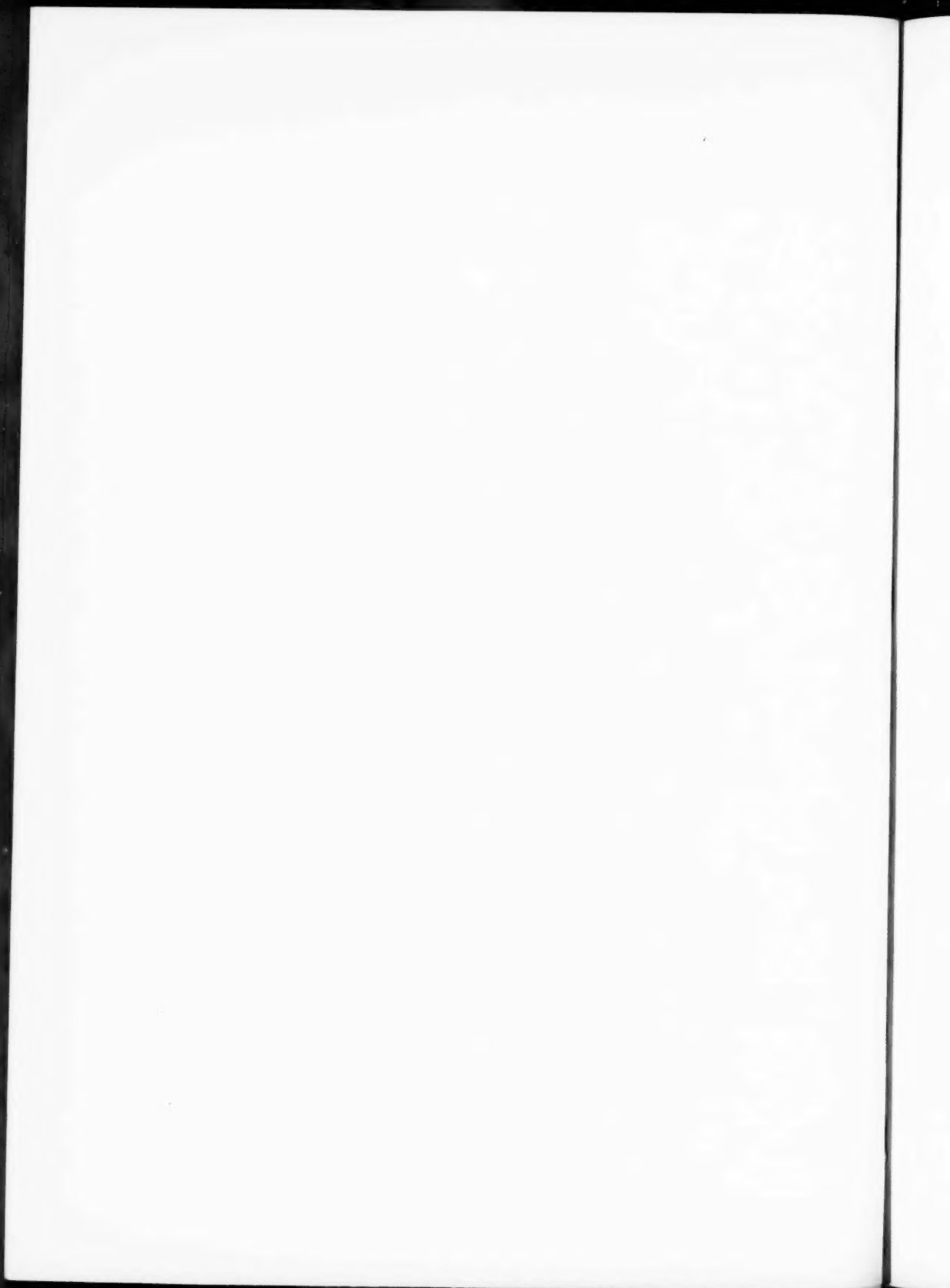
For

$$\begin{aligned} |(A)+i(S)|^2 &= \begin{vmatrix} (A) & i(S) \\ i(S) & (A) \end{vmatrix} = \begin{vmatrix} (A) & i(S) \\ i(S) & (A) \end{vmatrix} \cdot (-i)^n \cdot (i)^n, \\ &= \begin{vmatrix} (A) & (S) \\ i(S) & -i(A) \end{vmatrix} \cdot (i)^n = \begin{vmatrix} (A) & (S) \\ -(S) & (A) \end{vmatrix}, \end{aligned}$$

in corroboration of a deduction of Scorza's of 1913.*

RONDEBOSCH, S.A.,
26th September 1929.

* Giornale di Mat., li, pp. 335-342.



RESPIRATORY EXCHANGE IN THE FRESHWATER CRAB, *POTAMONAUTES PERLATUS*.

By ENID HOGGEN and ALEXANDER ZOOND.

From the Department of Zoology, University of Cape Town.

The literature of invertebrate comparative physiology can furnish relatively few data from which conclusions may be drawn regarding the definitely restricted localisation of respiratory function in invertebrate animals. Thus although the tracheal system in insects was described by Malpighi, it was not until the year 1914 that Krogh definitely proved its respiratory function by actual gas analysis of the tracheal air in *Orthoptera*. In one instance at least experiment has shown that the attribution of respiratory function to structures that bear a morphological resemblance to respiratory organs in other types was unwarranted. The work of Fox (1920) proved that the so-called anal gills of the larva of *Chironomus* have no special respiratory significance. In general it may be stated that a generalised cutaneous respiratory exchange, which in the higher vertebrates plays quite a negligible rôle, increases in extent and importance as we descend the animal scale, and is, in lowly organisms such as Planarians, the only mechanism by which equilibrium is maintained between the tissues and the gaseous environment. Thus in the stick insect, *Dixipus morosus*, it was found by Buddenbrock and Rohr (1923) that respiration through the skin or through the epithelia of the alimentary tract was 25 per cent. of the total respiratory exchange.

The present communication deals with an investigation of the respiratory exchange of the freshwater crab, *Potamonautes perlatus*, common in the streams and vleis of the Cape Peninsula. This animal is remarkable in that, although it is commonly found in water, it is known to wander on land during the dry season, and may be encountered far from sources of moisture. It is therefore both a water- and an air-breathing animal, and our experiments show that it can live successfully both when submerged in deep water and when kept in the total absence of moisture. In the latter condition it eventually dies, but rather from desiccation than from asphyxia. These facts are seen from the following table, which shows the duration of survival of animals kept at the bottom of tall glass cylinders filled with running tap-water, and of animals in dry containers in air.

TABLE I.—*Survival of Crabs in Air and in Deep Water.*

Medium.	Treatment.	No. of animals.	Survival duration.			
			One day.	Two days.	Three days.	Over three days.
Air .	Normal	6	0	0	0	6
	Claws removed	6	1	1	0	4
	Scaphognathites removed	6	1	1	1	3
Water .	Normal	6	0	0	0	6
	Claws removed	6	0	1	0	5
	Scaphognathites removed	6	6	0	0	0

The decapod crustacea are provided with a paddle-like appendage attached to the exopodite of the second maxilla, known as the scaphognathite, which projects into the gill chamber, and maintains a more or less continuous rhythmical motion so long as the animal is immersed in water. It was our object to inquire whether the structures described as gills are actually organs of localised gaseous exchange, and whether the scaphognathite performs a significant or an indispensable function in the respiratory mechanism. The scaphognathite is highly vascularised at its base, and simple removal by amputation invariably resulted in death from loss of blood. It was found possible, however, to detach the scaphognathites with the aid of a small electric cautery with little operative disturbance and scarcely any loss of blood. Animals so operated upon were found to survive in air as well as control animals that had been subjected to a similar degree of operative manipulation (Table I), but in deep water the scaphognathectomised individuals all died off within a few hours, the average period of survival being seven hours.

These results indicate that respiratory activity is very largely localised in the gills, and that the scaphognathite subserves a mechanical ventilating function which in water is indispensable, but without significance in air. It is well known that oxygen diffuses very slowly in water, and it is therefore not difficult to envisage how the slow diffusion of oxygen along the oxygen tension gradient existing between the respiratory surface of the gills and the external aqueous medium may be quite inadequate to maintain the necessary tension at the gill surface. The continuous current of water directed through the gill chambers by the scaphognathites serves to abolish

such a tension gradient. The constituent gases of the air, however, diffuse with comparative rapidity, and therefore it would seem that the intervention of the scaphognathites is not required to maintain an adequate supply of oxygen to the gill surfaces.

These assumptions were confirmed in a series of determinations of dissolved oxygen consumption and carbon dioxide production, the results of which are given in Tables II and III. Dissolved oxygen was determined by the modified Winkler method, as described in the Standard Methods of Water Analysis of the American Public Health Association. It is a peculiarity of the freshwater crab, and one which, we believe, is characteristic also of the freshwater crayfish, that it is able to survive successfully in distilled water. To facilitate the determination of dissolved carbon dioxide, distilled water was used in these experiments. The experimental animal was put into a glass cylinder containing one litre of water saturated with air by previous shaking. A layer of liquid paraffin was poured over the water to prevent diffusion of gas from the atmosphere. The efficacy of this procedure was checked by control determinations. At the end of one hour a sample of the water was syphoned over under oil without coming into contact with air, and the dissolved oxygen was determined. This value subtracted from the initial oxygen content of the water, previously determined, gave the amount of oxygen consumed by the crab. All results were reduced to oxygen consumption per kilogram per hour. The carbon dioxide production was estimated by a method which, though undoubtedly not delicate, has the advantage of extreme simplicity, and is in our opinion quite suitable for this particular purpose. It consists merely in adding an excess of baryta solution to an aliquot of the water and titrating the excess of hydroxide against standard hydrochloric acid solution. The method, of course, can only be used with distilled water where it is known that all the carbon dioxide exists as free carbonic acid. Control determinations on distilled water saturated with carbon dioxide showed that the method is accurate to within 10 per cent.

TABLE II.—*Oxygen Consumption in Water.*

Treatment.	No. of animals.	Oxygen, mgm. per kilo hour.	S.D. of mean.
Normal . . .	43	42.3	2.4
Scaphognathites removed . . .	25	3.5	0.56

Table II shows the oxygen consumption in water of normal and scaphognathectomised animals. The determinations showed great variability,

which is certainly not due to any error inherent in the method, but is to be ascribed to the lack of uniformity which invariably characterises determinations of respiratory exchange in whole animals. A fairly large number of determinations were therefore made and the results treated statistically. The statistical average and the standard deviation of the mean show quite conclusively that removal of the scaphognathites reduces the consumption of dissolved oxygen to about 8 per cent. of the normal, an observation which accounts quite adequately for the inability of the scaphognathectomised animals to survive in deep water.

TABLE III.—Carbon Dioxide Production in Water.

Treatment.	No. of animals.	Carbon dioxide, mgm. per kilo hour.	S.D. of mean.
Normal	27	62.5	4.5
Scaphognathites removed	16	8.1	1.1

Table III gives a similar series of determinations of the carbon dioxide produced. Again the removal of the scaphognathites abolishes the greater part of the respiratory exchange. The data for the oxygen consumption and carbon dioxide production of normal animals yield a respiratory quotient of 1.0—a figure which, seeing that the animals had not been fed for some days, provides satisfactory evidence of the accuracy of the methods.

The experimental data presented in this paper warrant the conclusion that the gills of *Potamonautes perlatus* are the main region of localised respiratory exchange, but that when the animal is immersed in water they are unable to function without the aid of the ventilating activity of the scaphognathites. In air, however, the scaphognathite is physiologically superfluous. Whether the residual respiratory activity of scaphognathectomised animals in water is due to a much-reduced gaseous exchange at the gills, or whether it represents a generalised cutaneous respiration, is at present uncertain.

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A COMPARATIVE STUDY ON THE SACRUM OF THE GRIQUA.

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(Communicated by Professor M. R. DRENNAN.)

This article is supplementary to a preliminary paper on the craniology of the Griquas published in 1924, and is based on material collected under assistance from the Government Research Grant Board, whose help we beg again fully to acknowledge.

Fourteen sacra were considered sufficiently well preserved and sufficiently authentic to be utilised in this study—owing to the marked variations in the vertebral column (which will be dealt with in another publication) the specimens were grouped as will presently appear.

The sacrum has always been the object of considerable attention in anthropological studies, more particularly since the classical work of Paterson. Partly this is because the sacra are often fairly well preserved in disinterred skeletons, and partly because the sacrum in itself shows variation of particular interest. We may refer here to Rosenberg's theory that the ilium migrates cranially during foetal life; whether this is true or not, we know that by the sixth week of intra-uterine life the pelvis attaches itself to the sacrum and after that time no shifting takes place. As regards variation in the number of segments comprising the sacrum, Le Double gives the following figures for 1528 sacra :—

Sacra with four segments . . . . .	. | .12 per cent.
Sacra with more than five segments . . . . .	. | 11.1 „

Ernest Warren, writing on the Nequada Race of early Egypt, found in 264 sacra the following, to which Emmons' figures for 207 European sacra are added :—

	Warren.	Emmons.
Sacra with four segments	2.65 per cent.	1.45 per cent.
Sacra with five segments, the first being imperfectly assimilated	2.27 „	.97 „
Sacra with six segments	6.06 „	15.46 „
Sacra with imperfectly assimilated sixth segment	6.06 „	.48 „

In Warren's works there were nearly twice as many female sacra as there were male among those showing abnormalities in numerical constitution—and in Wetzel's work, although male and female sacra shared equally in abnormal features, there were five times as many male sacra with five segments as there were female. We found no similar partition of the sexes in the Griquas studied.

Wetzel, studying the sacra of aboriginal Australians finds the percentages given below—to which we append figures for the Griquas :

	Australian.	Griqua. 14.
Sacra with four segments . . . . .	.. 2♀	.. 3♀
Sacra with five segments	54.5 per cent. 2♂	64.3 per cent. 6♂
Sacra with five segments and a lumbo-sacral vertebra showing assimilatory tendency	18.1 .. 3♀	7.1 .. 1♂
Sacra with six true segments	9.15 .. 2♂	21.5 .. 3♂
Sacra in which a sixth segment is obviously the fused first coccygeal	18.25 .. 2♀	7.1 .. 1♂
	2♂	

Comparative data are not available of abnormal sacra in Bush or Bantu, so we will confine ourselves to the normal sacrum of the Griqua in making genetic comparisons.

As regards sex, we must differ with the dictum that the female sacrum of any group is always wider than the male. Wetzel found just as wide male as female sacra among his Australians; and Warren, too, concluded that the "sacrum was found to be quite useless" in respect of determination of sex. The hip girdle is the safest guide.

Nevertheless it is true that in general the breadth of the sacrum tends to be greater in the female (in our Griquas the broadest individual sacrum was in fact among the females); but the relation of breadth to length is less irregular in the male. The sacral curvature is, on the whole, slightly deeper in males than females, and shows a greater tendency to flatness in the upper parts. (Warren found great curvature in male sacra, while some female were practically flat.)

The oldest and commonest way of expressing the proportions of the sacrum is by means of the linear length and the maximum breadth and the index derived from these :

	No.	Maximum Length.		Maximum Breadth.		Br. \times 100/L.	
		♂	♀	♂	♀	♂	♀
Bush	4	95.37		90		96.6	
(Shrubsall)	4		89.75		95.5		106.3
Hottentot	2	100		75		75	
(Fritsch)	1		95		81		85.3
Griqua	5	105.3		94.4		86.2	
	2		106		104		98.3
Bantu	7	102		93		92.8	
(Fritsch)	1		86		92		107
European		105		118		112.4	
(Verneau)			101		116		114.8

These measurements take no account whatever of the curvature of the sacrum, and for this reason Cunningham and others suggested various procedures; as, however, it is rare to find all these methods applied by any one observer, we have to make comparative studies suit the data available.

	Bush (Thompson). 3.	Griqua. 7.	Zulu (Benassi). 3.	European (Radlauer).
Max. Br. \times 100/ Tape L.	92.3	87.5	94.6	69.6
Curve D \times 100/ Tape L.	15.7	15.1	17.2	20.4
Call. L. \times 100/ Tape L. (Radlauer.)	96.2	95.5	90.9	86.5
Tape L. \times 100/ Call. L. (Wetzel.)	104.7	104.7	110.0	115.6

These various indices convey the proportions of the sacrum in different ways, and it will be seen that the Grikas give figures approximating to those of the Bush very closely in some respects; yet the actual size of the sacrum is considerably above that of the Bushman specimens and approaches far more closely the average size met in Europeans and Bantu.

The actual depth of the sacral arch in the sagittal plane is here indicated:

	Bush (Thompson).	Griqua (55).	Zulu (Benassi).	European (Martin).	Australian (Wetzel).
Depth at maxi- mum curvature)	16.16	16.9	18.3	25	19

In depth of the sacral curve the gorilla and orang among the anthropomorphs approach most closely to man (with average figures of 10.4 mm. and 10.6 mm.): in the chimpanzee the curvature is less, and in *hylobates* scarcely exists. In man, although curvature is present early in foetal life (at about the third month), it is not fully developed until the infant assumes the erect posture: yet the actual curve depth does not necessarily carry weight apart from its relation to other dimensions of the sacrum. The depth is, for example, apt to be very low (13 or 14 mm.—Martin) in many negroes, yet this does not of itself place them lower than the Australian or Bushman in the scale.

In an attempt to discern any differences in the sacral portion of the vertebral column corresponding with the variations in the presacral vertebrae, we have grouped our Griqua sacra as follows:—

Group 1. Sacra of five segments belonging to normal columns of either sex.

Group 2. Sacra belonging to columns with lumbo-sacral vertebrae.

Group 3. Sacra belonging to columns with a supernumerary presacral vertebra.

Group 4. Sacra with six segments belonging to columns otherwise normal.

This classification finds justification in the fact that the sacrum is indeed part of the vertebral column, though a particularly specialised portion . . . specialised for stability; even as the axis and atlas are specialised in the opposite direction for mobility. Moreover, the sacra in each of these groups show definite peculiarities.

Group 1. Sacra (5 males, 2 females).

In general, we have shown therefore that the shallowness of the sacrum in the Griqua is the feature in which it approaches the Bushman most nearly, and therein departs most from European and Bantu types. Both the length and the breadth of the sacrum conform most closely to the dimensions in European and Bantu—in these respects, incidentally, the Griqua female approaches these higher races more closely than the male. Yet it is chiefly in size that the Griqua sacrum is reminiscent, more particularly, of that of the Bantu—in proportions, the Bushman is often recalled by the various indices found for the Griqua, but never exactly imitated.

Group 2. Sacra (1 male, also included in Group 3).

Wetzel found that in Australian sacra of five segments associated with a lumbo-sacral vertebra, the length of the sacrum is shorter than in the

normal and the curve is greater. The same features were marked in our material also.

		Calliper L.	Tape L.	Curve D.	Tape L. \times 100 Call. L.	Curve D \times 100 Tape L.
Normal sacrum	{ Aust. Griq. 5♂	115	122	24	106.1	19.7
		105.3	110.3	16.9	103.9	16.2
Sacrum asso- ciated with lumbo-sacral vert.	{ Aust. Griq. 1♂	84	93	24	110.8	25.8
		88	101	21	114.7	20.7

Group 3. Sacra (2 males, 1 female).

Very similar deviations from the normal sacral proportions were, however, found to characterise those sacra accompanying spines with 25 pre-sacral vertebrae, marking them clearly and constantly from normal specimens; in both females and males was this true.

	Sex.	Calliper L.	Tape L.	Curve D.	Breadth.	Br. \times 100/ Tape L.	Tape L. \times 100/ Call. L.	Curve D \times 100/ Tape L.
Sacra associated with 25 pre- sacral vertebrae	2♂	81.5	93.5	21	85.5	91.5	114.6	22.5
	1♀	86	93	16	84	90.3	110.4	17.2
Normal sacra	5♂	105.3	110.3	16.9	94.4	85.8	103.9	15.3
	2♀	106.0	109.0	13	104	91.0	102.8	12.0

The sacra of the abnormal series are thus shorter and narrower, but relatively much deeper than the normal. That increase in the vertebral number is a primitive feature, the character of the accompanying sacrum here does not in any way support.

Group 4. Sacra (4 males).

On the other hand, sacra of six segments showed particular abnormality in the relative flatness of the curve (as shown by the absolute maximal depth) and also in some reduction in breadth. If one separates the sacra in which the sixth segment is an obviously fused first caudal vertebra from those in

which there are six true sacral vertebrae, it will be seen that a considerable difference exists between these two types—paralleled again in Wetzel's Australian series.

		Br. \times 100/ Call. L.	Tape L. \times 100/ Call. L.
Sacra with six true sacral segments	Australian 2	73.0	108
	Griqua 3	80.4	103.2
	Australian 4	104	114
Sixth sacral segment a fused first coccygeal	Griqua 1	102.2	107.6

The differences here are not as great as in the Australian—but nevertheless between the normal and the two abnormal series there is a very distinct discrepancy :

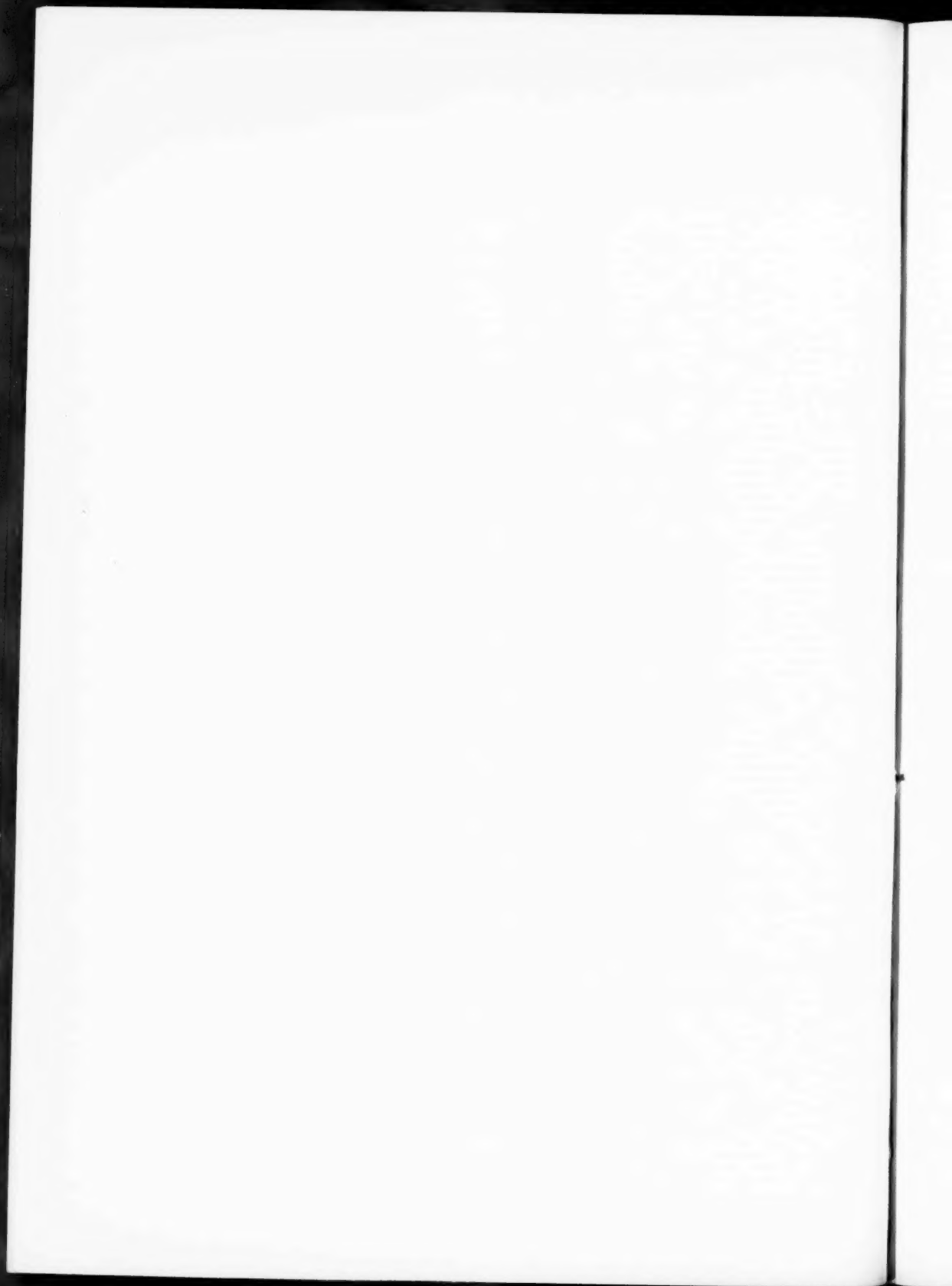
	Calliper L.	Tape L.	Curve D.	Sacral Br.	Br. \times 100/ Tape L.	Tape L. \times 100/ Call. L.	Curve D. \times 100/ Tape L.
Sacra with six true sacral segments	109	112.6	13.6	88	78.2	103.2	12.0
Sacral with a fused first coccygeal	91	98	14	93	94.9	107.6	14.2
Normal males	105.3	115.3	16.9	94.4	85.8	103.9	15.3

Although fusion of a true sixth segment into the sacrum is reminiscent of what is normal in some anthropoids, the six-segmented Orang sacrum differs just as widely from the six-segmented sacrum of the Australian and the Griqua, as it does from the normal sacra of five vertebrae in these races. It can thus scarcely be considered as an anthropoid trait.

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THE CAUSE OF THE RUSSELL EFFECT OBSERVED IN OILS.

By J. C. VOGEL.

(Communicated by the Honorary General Secretary.)

Russell * has shown that wood and nearly all vegetable tissues act on sensitive photographic plates in the absence of light, forming dark images. The effect is most striking in material containing resins and gums, and is accelerated by heat. The presence of oxygen is necessary, and an atmosphere of carbon dioxide inhibits the action. Contact between the plate and the organic matter is not necessary, and screens of paper do not prevent the formation of an image on the plate, though screens of glass, mica, or aluminium foil do. Schmidt † observed a similar effect using linseed-oil varnish, and suggested that this may be due to radiation. Reklings ‡ has shown that cod-liver oil is photoactive in its native condition, whereas olive and linseed oils only acquire activity after irradiation, and then only in the presence of oxygen. The acquired activity of these latter oils he found to be removable by a current of air, but the activity of cod-liver oil was not removable by this means. Van der Lingen § has shown that this photoactivity, which he observed in a number of animal, vegetable, and mineral oils, is not due to a radiation from the oils but to the evolution of a gaseous product, and that the penetration of the effect through paper is due to the presence of small pinholes and porous spaces in the screen. The usual explanation given for the phenomenon is that hydrogen peroxide or ozone is given off during the slow oxidation of the oil and that these gases cause the Russell effect.

The chemical investigation of the nature of the Russell effect observed in oils was suggested to the author by Dr. J. S. van der Lingen of the Department of Applied Mathematics of the University of Capetown and forms the subject of this publication.

If the formation of a potential image on a photographic plate on exposure to an oil be due to the liberation of hydrogen peroxide or ozone during the

* Proc. Roy. Soc., B, lxxviii, 385 (1907); lxxx, 376 (1908).

† Zeits. Physik. Chem., lxi, 243 (1908).

‡ Ber. ges. Physiol. exper. Pharmacol., xl, 177 (1927).

§ South African Journ. of Scien., xxiii, 223 (1926).

oxidation of the oil, then, under similar conditions, the oil should also affect starch-potassium iodide paper. In order to determine whether this be the case, a number of animal and vegetable oils were exposed in small dishes, the tops of which were covered with moist starch-potassium iodide paper. The dishes were enclosed in a metal box containing water in order to prevent the drying out of the starch-iodide paper and allowed to remain in the dark for six days. Within a few hours some of the papers covering the oils began to show blue stains, and at the end of the period all the papers were more or less stained. The following column A is a list of the oils in order of decreasing intensity of the stain produced on starch-iodide paper. In column B is recorded the order of intensity of the image produced in the dark on a photographic plate by these oils as determined by Dr. van der Lingen.

A	B
Olive oil I.	Olive oil I.
Lucca oil.	Lucca oil.
Cod-liver oil I.	Cod-liver oil I.
Whale-meat oil.	Whale-meat oil.
Linseed oil I.	Linseed oil I.
Cod-liver oil II.	Whale-blubber oil.
Whale-blubber oil.	Cod-liver oil II.
Cotton-seed oil.	Linseed oil II.
Linseed oil II.	Nut oil.
Nut oil.	Cotton-seed oil.
Olive oil II.	Olive oil II.
Castor oil.	Castor oil.
Ground-nut oil.	Ground-nut oil.
Olive oil III.	Olive oil III.
Neatsfoot oil.	Neatsfoot oil.

The above two series are substantially the same; the irregularities are probably due to the fact that, whereas the order of intensity of the images on the photographic plates is fairly easily determined, the relative intensities of the starch-iodide paper stains are much more difficult to judge correctly. On exposure of the oils to moist starch-iodide paper in a desiccator from which all the air had been pumped out, but which contained a dish of water in order to prevent the drying out of the paper, no stain on the paper was observable even after a week's exposure. It is thus evident that air is as necessary for the production of the iodine stain as it is for the photographic image. It would appear from these results that the iodine stains are due to the same causes as the images produced on a photographic plate.

On blowing a current of air through a sample of cod-liver oil I in a small

wash-bottle it was found that a piece of starch-iodide paper held to the exit of the wash-bottle was stained blue within a minute, showing that, under these conditions, the liberation of appreciable quantities of the active vapours from the oil is very rapid. On blowing a current of carbon dioxide through the oil it was found that at first the gas at the exit of the wash-bottle liberated iodine from potassium iodide, but that after a short while the development of the stain ceased and no further stain could be obtained on fresh starch-iodide paper. On again blowing air through the same oil its activity was immediately restored. The same results were obtained with olive oil I. This confirms the fact that air is necessary for the production of the stain and that it is due to the liberation of a gaseous by-product during the slow oxidation of the oil by the air. The persistence of the activity of the oil on first blowing with carbon dioxide is probably due to the expulsion by the gas of a small amount of the active constituent which is dissolved in the oil.

The identification of the vapour given off by the oils on exposure to the air was next attempted. A slow, steady current of air was sucked first through a series of wash-bottles containing concentrated potassium hydroxide solution in which the air was completely freed from carbon dioxide, then through a small bubbler containing 2 c.c. of olive oil I, then through a quartz tube, a water-cooled condenser, and finally through a bubbler containing 10 c.c. of a 0.1 N solution of pure potassium iodide in distilled water. On sucking air through this apparatus the iodide solution became coloured yellow owing to the liberation of iodine. After three hours the iodine liberated was titrated with 0.01 N thiosulphate solution in the presence of starch. 0.1 c.c. of thiosulphate was required. On immersing the oil bubbler in a boiling-water bath the rate of iodine liberation was much increased, 1.5 c.c. of the thiosulphate solution being required for the titration of the iodine liberated in three hours. On strongly heating the quartz tube during the passage of the air through the apparatus it was found that no iodine was liberated in the potassium iodide bubbler. Blank tests in the absence of oil failed to show any trace of iodine liberation under the conditions of any of the preceding experiments. These experiments show that the activity of the oil is not primarily due to a reaction taking place in or at the surface of the oil but that it is due to the formation, during the oxidation of the oil, of a gaseous product which can be removed from proximity to the oil without destroying its activity. The rate of liberation of this gas is accelerated by increasing the temperature of the oil during oxidation, and the gas itself is decomposed at high temperatures. If this active gas be ozone or hydrogen peroxide, then the liberation of iodine in the potassium iodide bubbler should be accompanied by an increase in the alkalinity of the solution owing to the reaction $2\text{KI} + \text{H}_2\text{O}_2 = 2\text{KOH} + \text{I}_2$.

It was actually found that the liberation of iodine in the above experiments was accompanied by an increase in the acidity of the potassium iodide solution. Tests carried out in the absence of oil showed no such increase in acidity; it could not, therefore, be due to the presence of acid constituents of the air sucked through the apparatus. Both ozone and hydrogen peroxide give delicate colour reactions with a saturated alcoholic solution of benzidine in the presence of copper sulphate. On replacing the potassium iodide bubbler with one containing a saturated alcoholic solution of benzidine, and passing air through the apparatus for six hours and then adding a drop of copper sulphate solution to the benzidine, no trace of the brown colour which is developed in the presence of ozone or of the blue colour obtained in the presence of hydrogen peroxide could be detected. From these experiments it would appear that the activity of the oils is not due to the formation of ozone or hydrogen peroxide.

It was found that the activity of the gases given off during the oxidation in the air of olive oil I could be destroyed by passing the gases through sodium hydroxide solution. A slow current of air, freed from carbon dioxide, was drawn continuously for one month through a bubbler containing olive oil I, then through a bubbler containing 1.0 N sodium hydroxide solution, and finally through one containing potassium iodide. The oil was replaced with fresh every three days. No iodine was liberated from the iodide during this experiment, the active oxidation products of the oil being completely absorbed by the sodium hydroxide solution. This solution was acidified with sulphuric acid and distilled. The distillate consisted of a solution smelling of butyric acid together with a small amount of a waxy solid of low melting-point which was apparently stearic acid. The distillate had an acid reaction and, on warming with ethyl alcohol and sulphuric acid, gave the characteristic pineapple odour of ethyl butyrate, indicating the presence of butyric acid. On adding to the distillate a drop of ferric chloride solution the latter was reduced and gave with potassium ferricyanide a Prussian blue precipitate. Oxyacids were apparently not present in the solution. Both acid and alkaline potassium permanganate solutions were reduced by the distillate, the latter yielding a solution which gave a negative test for oxyacids with ferric chloride. This indicates that no isobutyric acid was present in the distillate.* All the above reactions are given by butyric acid. A piece of starch-iodide paper exposed over a crucible containing some of the distillate rapidly developed a blue stain. A weak solution of butyric acid under the same conditions gave a similar result. These results indicate that one of the oxidation products of the oil is normal butyric acid and that this acid is capable of producing the Russell effect observed.

* Meyer u. Jacobson, *Organischen Chemie* (2nd ed.), Berlin, 1922, vol. i, p. 532.

On neutralising the filtered distillate obtained in the manner described above with sodium hydroxide and adding barium chloride, a flocculent precipitate was obtained. This precipitate was filtered, washed, and dried at 110° C. It was found to be a mixture of barium salts of organic acids containing 49.8 per cent. of barium. The average molecular weight of these acids is therefore 140, which corresponds to caprylic acid (mol. wt. = 144). It is therefore evident that the distillate contains higher fatty acids in addition to butyric acid. From cod-liver oil, by a similar method, a distillate was obtained which contained very little butyric acid, but a considerable amount of normal fatty acids of the average molecular weight of 145. It has been shown * that normal fatty acids containing from four to ten carbon atoms are formed during the oxidation of stearic and oleic acids. Evidently these acids are also produced during the oxidation in the air of oils, and it is their vapour which reduces the silver salts on a photographic plate, thus producing the Russell effect. The oxidation of potassium iodide to iodine when exposed to oils oxidising in the air is due to the evolution of these fatty acids which liberate hydriodic acid from the iodide, which acid is subsequently oxidised to iodine by atmospheric oxygen. This view is supported by the occurrence of acid in the oxidised potassium iodide solution. It is known that petroleum oils, on exposure to air, are slowly oxidised, with the production of organic peroxides together with simple organic acids such as butyric acid and other oxidation products.† The action of four samples of lubricating oils on photographic plates and on starch-iodide paper was investigated and it was found that they behaved similarly to the other oils tested. The intensities of the images developed on the plates were in the same order as the intensities of the iodine stains obtained on iodide paper. This effect is probably also due to the evolution of butyric and similar acids, since the peroxides formed on oxidation are not volatile‡ and do not, therefore, come in contact with the photographic plates.

In order to determine whether the intensity of the Russell effect produced is proportional to the rate of oxidation of the unsaturated acid constituents of the oils, air was drawn at a constant rate for a period of twenty hours through 2 grms. of oil contained in a bubbler immersed in boiling water. The iodine number of the original oil and of the sample thus oxidised was determined. The decrease in the iodine number observed is a measure of the rate of oxidation of the unsaturated constituents of the oil. These determinations were carried out on all the active oils listed in column A. It was found that the activities of the four samples of olive oil were inversely

* Meyer u. Jacobson, *Organischen Chemie* (2nd ed.), Berlin, 1922, vol. i, pp. 534, 539.

† Brooks, *The Non-benzoid Hydrocarbons*, N.Y., 1922, p. 427.

‡ Engler u. Weissberg, *Ber.*, xxxiii, 1094 (1900).

proportional to their iodine numbers and the same applied to the four samples of mineral lubricating oils. No general relationship was observable, however, between either the degree of unsaturation as measured by the iodine number or the rate of oxidation of the unsaturated constituents of the oils and the intensity of the Russell effect produced by the respective oils.

I wish to express my thanks to Dr. J. S. van der Lingen of the University of Capetown for supplying samples of oils and for his collaboration during the course of this investigation.

NOTE ON SUMS OF n -LINE MINORS PERTAINING
TO AN n -BY- $(n+2)$ ARRAY.

By Sir THOMAS MUIR, F.R.S.

1. The main theorem reached here may be stated as follows: *If from any n -by- $(n+2)$ array there be formed four determinants, namely,*

$$\begin{array}{llllll} \text{P} & \text{by omitting the} & n^{\text{th}} & \text{and } (n+2)^{\text{th}} & \text{columns,} & \\ \text{Q} & \text{,,} & \text{,,} & (n+1)^{\text{th}} & \text{and } 1^{\text{st}} & \text{,,} \\ \text{Y} & \text{,,} & \text{,,} & (n-1)^{\text{th}} & \text{and } (n+2)^{\text{th}} & \text{,,} \\ \text{Z} & \text{,,} & \text{,,} & n^{\text{th}} & \text{and } (n+1)^{\text{th}} & \text{,,} \end{array}$$

then the sum, \sum say, of the determinants which each have $n-1$ rows in common with P and 1 row in common with Q is equal to the sum of Y and Z,

$$\text{i.e. } \sum = Y + Z.$$

As an example let us take $n=4$, the 4-by-6 basic array being

$$\begin{array}{cccccc} a_1 & a_2 & a_3 & a_4 & a_5 & a_6 \\ b_1 & b_2 & b_3 & b_4 & b_5 & b_6 \\ c_1 & c_2 & c_3 & c_4 & c_5 & c_6 \\ d_1 & d_2 & d_3 & d_4 & d_5 & d_6 \end{array}$$

The two auxiliary minors P and Q are thus

$$\left| \begin{array}{cccc} a_1 & a_2 & a_3 & a_5 \\ b_1 & b_2 & b_3 & b_5 \\ c_1 & c_2 & c_3 & c_5 \\ d_1 & d_2 & d_3 & d_5 \end{array} \right|, \quad \left| \begin{array}{cccc} a_2 & a_3 & a_4 & a_6 \\ b_2 & b_3 & b_4 & b_6 \\ c_2 & c_3 & c_4 & c_6 \\ d_2 & d_3 & d_4 & d_6 \end{array} \right|,$$

the sum \sum constructed therefrom is

$$\left| \begin{array}{cccc} a_1 & a_2 & a_3 & a_5 \\ b_1 & b_2 & b_3 & b_5 \\ c_1 & c_2 & c_3 & c_5 \\ d_2 & d_3 & d_4 & d_6 \end{array} \right| + \left| \begin{array}{cccc} a_1 & a_2 & a_3 & a_5 \\ b_1 & b_2 & b_3 & b_5 \\ c_2 & c_3 & c_4 & c_6 \\ d_1 & d_2 & d_3 & d_5 \end{array} \right| + \left| \begin{array}{cccc} a_1 & a_2 & a_3 & a_5 \\ b_2 & b_3 & b_4 & b_6 \\ c_1 & c_2 & c_3 & c_5 \\ d_1 & d_2 & d_3 & d_5 \end{array} \right| + \left| \begin{array}{cccc} a_2 & a_3 & a_4 & a_6 \\ b_1 & b_2 & b_3 & b_5 \\ c_1 & c_2 & c_3 & c_5 \\ d_1 & d_2 & d_3 & d_5 \end{array} \right|;$$

and as the two other minors Y and Z of the original array are

$$\left| \begin{array}{cccc} a_1 & b_2 & c_4 & d_5 \end{array} \right|, \quad \left| \begin{array}{cccc} a_1 & b_2 & c_3 & d_6 \end{array} \right|,$$

the identity in question, $\sum = Y + Z$, is before us.

2. In proof of this we first note that each of the elements d_6, c_6, b_6, a_6 has the same cofactor in the left member as in the right, and consequently may be left out of account. In the next place the like is seen to be true of the elements d_4, c_4, b_4, a_4 , and these also may go. All that thus requires to be proved is

$$\begin{vmatrix} a_1 & a_2 & a_3 & a_5 \\ b_1 & b_2 & b_3 & b_5 \\ c_1 & c_2 & c_3 & c_5 \\ d_2 & d_3 & . & . \end{vmatrix} + \begin{vmatrix} a_1 & a_2 & a_3 & a_5 \\ b_1 & b_2 & b_3 & b_5 \\ c_2 & c_3 & . & . \\ d_1 & d_2 & d_3 & d_4 \end{vmatrix} + \begin{vmatrix} a_1 & a_2 & a_3 & a_5 \\ b_2 & b_3 & . & . \\ c_1 & c_2 & c_3 & c_5 \\ d_1 & d_2 & d_3 & d_5 \end{vmatrix} + \begin{vmatrix} a_2 & a_3 & . & . \\ b_1 & b_2 & b_3 & b_5 \\ c_1 & c_2 & c_3 & c_5 \\ d_1 & d_2 & d_3 & d_5 \end{vmatrix} = 0.$$

Fixing our attention, thirdly, on the two-line minors of the last pair of columns of each determinant, we find that

$$\begin{aligned} \text{cofactor of } \begin{vmatrix} a_3 & b_5 \end{vmatrix} & \text{ is } \begin{vmatrix} c_1 & c_3 \\ d_2 & d_3 \end{vmatrix} + \begin{vmatrix} c_2 & c_3 \\ d_1 & d_2 \end{vmatrix} \quad \text{i.e. } \begin{vmatrix} c_1 & d_3 \end{vmatrix}, \\ \text{cofactor of } - \begin{vmatrix} a_3 & c_5 \end{vmatrix} & \text{ is } \begin{vmatrix} b_1 & b_2 \\ d_2 & d_3 \end{vmatrix} + \begin{vmatrix} b_2 & b_3 \\ d_1 & d_2 \end{vmatrix} \quad \text{i.e. } \begin{vmatrix} b_1 & d_3 \end{vmatrix}, \\ \text{and cofactor of } \begin{vmatrix} c_3 & d_5 \end{vmatrix} & \text{ is } \begin{vmatrix} a_1 & a_2 \\ b_2 & b_3 \end{vmatrix} + \begin{vmatrix} a_2 & a_3 \\ b_1 & b_2 \end{vmatrix} \quad \text{i.e. } \begin{vmatrix} a_1 & b_3 \end{vmatrix}. \end{aligned}$$

This means that our sum of four determinants is expressible as one, namely,

$$\begin{vmatrix} a_1 & a_3 & a_3 & a_5 \\ b_1 & b_3 & b_3 & b_5 \\ c_1 & c_3 & c_3 & c_5 \\ d_1 & d_3 & d_3 & d_5 \end{vmatrix},$$

which has two of its columns identical, and therefore vanishes. A quite general proof of a different type is referred to below.

3. In constructing the determinants of \sum it will have been noticed that a seeming preference is given to P over Q, in the selection of material, so to say. We are thus led to inquire what the result would have been if Q had had the preference: and the answer is that the sum would then have been

$$\begin{vmatrix} a_1 & b_3 & c_4 & d_6 \end{vmatrix} + \begin{vmatrix} a_2 & b_3 & c_4 & d_5 \end{vmatrix};$$

and generally would have been

$$\sum' = Y' + Z',$$

where the basic n -by- $(n+2)$ array gives

Y' on the omission of the 2^{nd} and $(n+1)^{\text{th}}$ columns,

and

Z' " " " " 1^{st} and $(n+2)^{\text{th}}$ " "

4. The first known theorem of this type we owe to Le Paige, who published it in the Liège Memoirs of 1880 (see Hist. of Dets., iv, p. 4), the basic array for it being not n -by- $(n+2)$, but n -by- $(n+1)$. The enunciation which we have given of our theorem has been purposely drafted on the lines of Le Paige's, in order that for shortness' sake we might be able to say that the old proof is readily extensible to the new theorem.

5. Another mode of presentation of the subject we may bring to notice by using it in Le Paige's case. The enunciation then takes the form: *Any n-line determinant, D, may be expressed as the sum of n determinants of the same order in each of which a fixed set of n new elements takes the place of n of the elements of D.* For example, when n is 4 and D is $|a_1 \ b_2 \ c_3 \ d_4|$, and the set of new elements is $\phi_1, \phi_2, \phi_3, \phi_4$, we have

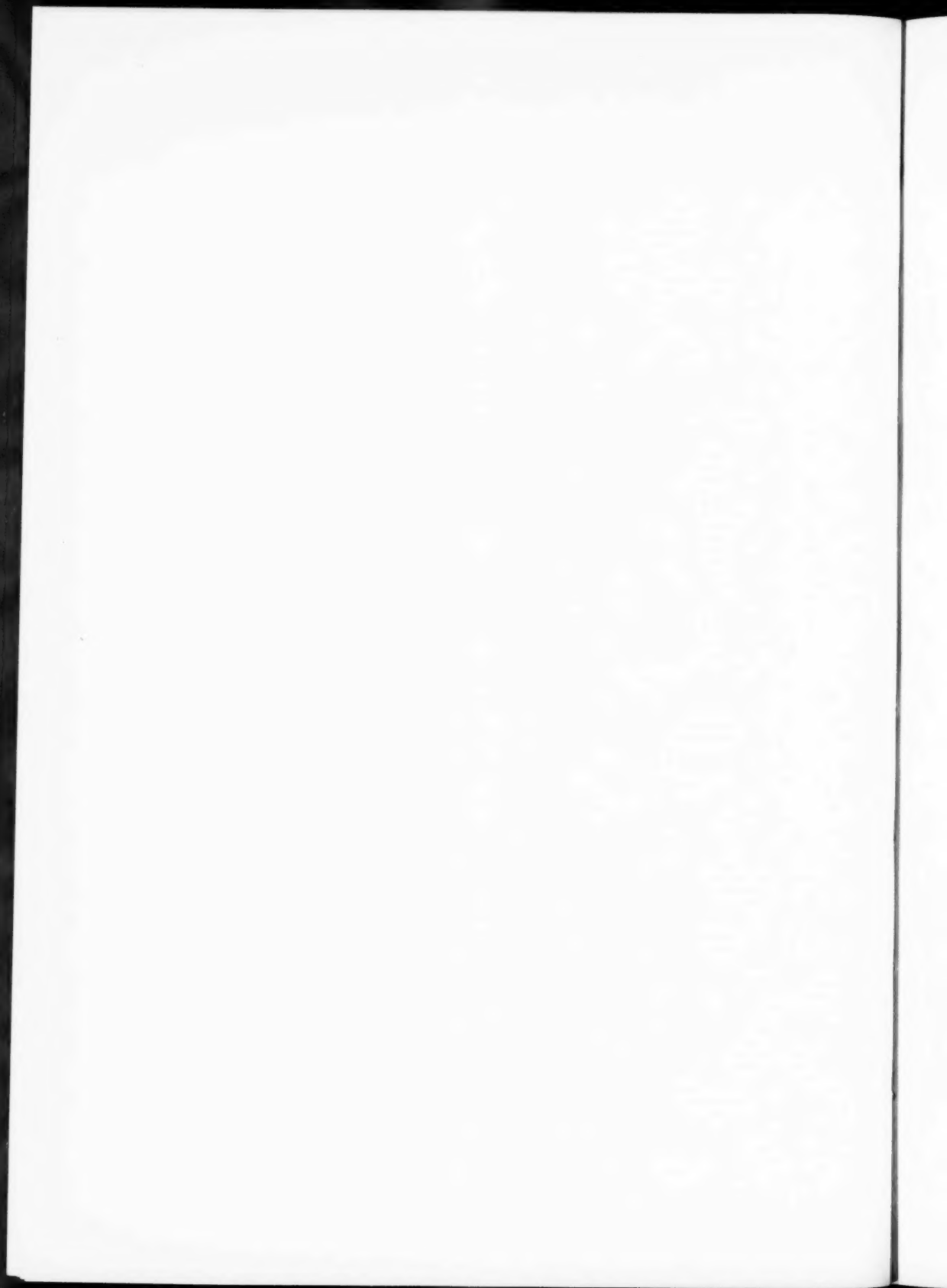
$$|a_1 \ b_2 \ c_3 \ d_4| = \begin{vmatrix} a_1 & a_2 & a_3 & b_1 \\ b_1 & b_2 & b_3 & c_4 \\ c_1 & c_2 & c_3 & \phi_4 \\ \phi_1 & \phi_2 & \phi_3 & d_4 \end{vmatrix} + \begin{vmatrix} a_1 & a_2 & b_3 & a_4 \\ b_1 & b_2 & c_3 & b_4 \\ c_1 & c_2 & \phi_3 & c_4 \\ \phi_1 & \phi_2 & d_3 & \phi_4 \end{vmatrix} + \begin{vmatrix} a_1 & b_2 & a_3 & a_4 \\ b_1 & c_2 & b_3 & b_4 \\ c_1 & \phi_2 & c_3 & c_4 \\ \phi_1 & d_2 & \phi_3 & \phi_4 \end{vmatrix} + \begin{vmatrix} b_1 & a_2 & a_3 & a_4 \\ c_1 & b_2 & b_3 & b_4 \\ \phi_1 & c_2 & c_3 & c_4 \\ d_1 & \phi_2 & \phi_3 & \phi_4 \end{vmatrix},$$

and, on taking advantage of the fact that only one d occurs in each determinant on the right,

$$0 = \begin{vmatrix} a_1 & a_2 & a_3 & b_4 \\ b_1 & b_2 & b_3 & c_4 \\ c_1 & c_2 & c_3 & \phi_4 \\ \phi_1 & \phi_2 & \phi_3 & . \end{vmatrix} + \begin{vmatrix} a_1 & a_2 & b_3 & a_4 \\ b_1 & b_2 & c_3 & b_4 \\ c_1 & c_2 & \phi_3 & c_4 \\ \phi_1 & \phi_2 & . & \phi_4 \end{vmatrix} + \begin{vmatrix} a_1 & b_2 & a_3 & a_4 \\ b_1 & c_2 & b_3 & b_4 \\ c_1 & \phi_2 & c_3 & c_4 \\ \phi_1 & . & \phi_3 & \phi_4 \end{vmatrix} + \begin{vmatrix} b_1 & a_2 & a_3 & a_4 \\ c_1 & b_2 & b_3 & b_4 \\ \phi_1 & c_2 & c_3 & c_4 \\ . & \phi_2 & \phi_3 & \phi_4 \end{vmatrix}$$

in which are involved only the elements of $|a_1 \ b_2 \ c_3 \ \phi_4|$.

6. It may be useful to note in conclusion that Le Paige's work was taken up and generalised by J. Deruyts in 1882 (see Hist. of Dets., iv, pp. 15-16): also that the most recent contribution to the subject is by L. L. Dines in the American Journ. of Math., xlvii, pp. 249-256. With the latter the basic array is square: the equalities above in which zero elements occur (§§ 2, 5) serve as simple illustrative instances of his very general theorem.



NOTE ON THE DERIVATIVES OF THE ELIMINANT OF TWO BINARY CUBICS.

By Sir THOMAS MUIR, F.R.S.

1. In regard to the cubics

$$\begin{aligned} ax^3+bx^2+cx+d=0, \\ px^3+qx^2+rx+s=0, \end{aligned}$$

we have the familiar facts that their resultant

$$\begin{aligned} R &= \begin{vmatrix} a & b & c & d & . & . \\ . & a & b & c & d & . \\ . & . & a & b & c & d \\ p & q & r & s & . & . \\ . & p & q & r & s & . \\ . & . & p & q & r & s \end{vmatrix}, \\ &= - \begin{vmatrix} a & b \\ p & q \end{vmatrix} \begin{vmatrix} a & c \\ p & r \end{vmatrix} \begin{vmatrix} a & d \\ p & s \end{vmatrix} \\ &\quad + \begin{vmatrix} a & c \\ p & r \end{vmatrix} \begin{vmatrix} a & d \\ p & s \end{vmatrix} \begin{vmatrix} b & c \\ q & r \end{vmatrix} \begin{vmatrix} b & d \\ q & s \end{vmatrix} \\ &\quad + \begin{vmatrix} a & d \\ p & s \end{vmatrix} \begin{vmatrix} b & c \\ q & r \end{vmatrix} \begin{vmatrix} b & d \\ q & s \end{vmatrix} \\ &\quad + \begin{vmatrix} a & d \\ p & s \end{vmatrix} \begin{vmatrix} c & d \\ r & s \end{vmatrix} \begin{vmatrix} b & c \\ q & r \end{vmatrix} \\ &= U^3 + M^2W + LV^2 - 2LUW - LNW - MUV; \end{aligned}$$

the third form being the ordinary expansion of the second when we write L, M, N, U, V, W for the two-line minors of the array of given coefficients, namely,

$$\begin{aligned} L, M, N &\text{ for } aq-bp, ar-cp, br-cq, \\ U, V, W &\text{ for } as-dp, bs-dq, cs-dr; \end{aligned}$$

and being Laplace's expansion of the first in terms of the 2-line minors of its 1st and 4th rows, its 2nd and 5th rows, and its 3rd and 6th rows.

2. Almost equally well known is the further fact that the 2-line minors of the array

$$\begin{vmatrix} \frac{\partial R}{\partial a} & \frac{\partial R}{\partial b} & \frac{\partial R}{\partial c} & \frac{\partial R}{\partial d} \\ \frac{\partial R}{\partial p} & \frac{\partial R}{\partial q} & \frac{\partial R}{\partial r} & \frac{\partial R}{\partial s} \end{vmatrix}$$

each contain R as a factor—a result apparently first drawn attention to in the 1866 edition of Salmon's *Modern Higher Algebra* (pp. 76–77). It is there reached by inference from the fact that the said minors vanish simultaneously with R . The object of the present notelet is to show what advantage accrues from adopting, on the other hand, a perfectly direct method of proof.

3. Taking then the dialytic eliminant in the form

$$- \begin{vmatrix} a & b & c & d & . & . \\ p & q & r & s & . & . \\ . & a & b & c & d & . \\ . & p & q & r & s & . \\ . & . & a & b & c & d \\ . & . & p & q & r & s \end{vmatrix}$$

and differentiating columns with respect to a , we obtain

$$\frac{\partial R}{\partial a} = - \begin{vmatrix} q & r & s & . & . \\ a & b & c & d & . \\ p & q & r & s & . \\ . & a & b & c & d \\ . & p & q & r & s \end{vmatrix} + \begin{vmatrix} a & c & d & . & . \\ p & r & s & . & . \\ . & q & r & s & . \\ . & a & b & c & d \\ . & p & q & r & s \end{vmatrix} - \begin{vmatrix} a & b & d & . & . \\ p & q & s & . & . \\ . & a & c & d & . \\ . & p & r & s & . \\ . & . & q & r & s \end{vmatrix}$$

where each determinant is composed of two pairs of rows and an unmatched row which has for its elements q, r, s and two zeros. From this it follows that $\partial R / \partial a$ is expressible in terms of q, r, s and 2-line minors of the array

$$\begin{matrix} a & b & c & d \\ p & q & r & s. \end{matrix}$$

As a matter of fact it will be seen that we have

$$\begin{aligned} \frac{\partial R}{\partial a} = & -q \begin{vmatrix} b & c & d & . \\ q & r & s & . \\ a & b & c & d \\ p & q & r & s \end{vmatrix} - q \begin{vmatrix} a & d & . & . \\ p & s & . & . \\ . & b & c & d \\ . & q & r & s \end{vmatrix} - q \begin{vmatrix} a & b & . & . \\ p & q & . & . \\ . & a & d & . \\ . & p & s & . \end{vmatrix} \\ & + r \begin{vmatrix} a & c & d & . \\ p & r & s & . \\ . & b & c & d \\ . & q & r & s \end{vmatrix} + r \begin{vmatrix} a & c & . & . \\ p & r & . & . \\ . & a & c & d \\ . & p & r & s \end{vmatrix} + r \begin{vmatrix} a & b & d & . \\ p & q & s & . \\ . & a & c & . \\ . & p & r & . \end{vmatrix} \end{aligned}$$

$$-s \begin{vmatrix} a & b & d & . \\ p & q & s & . \\ . & a & c & d \\ . & p & r & s \end{vmatrix} -s \begin{vmatrix} a & c & d & . \\ p & r & s & . \\ . & a & b & d \\ . & p & q & s \end{vmatrix} -s \begin{vmatrix} a & b & d & . \\ p & q & s & . \\ . & a & c & d \\ . & p & r & s \end{vmatrix} \\ =q(-NW+V^2-2UW)+r(2MW-UV)+s(-2LW+3U^2-MV).$$

And by proceeding in similar fashion we obtain

$$\begin{aligned} \frac{\partial R}{\partial b} &= -p(-NW+V^2-2UW) & +r(-LW) & +s(2LV-MU), \\ \frac{\partial R}{\partial c} &= -p(2MW-UV) & +q(LW) & +s(M^2-2LU-LN), \\ \frac{\partial R}{\partial d} &= -p(-2LW+3U^2-MV) & -q(2LV-MU) & -r(M^2-2LU-LN). \end{aligned}$$

4. A notable feature of these four equalities, which we may agree to write shortly in the form

$$\begin{aligned} \frac{\partial R}{\partial a} &= qF_{12}+rF_{13}+sF_{14}, \\ \frac{\partial R}{\partial b} &= -pF_{12} & +rF_{23}+sF_{24}, \\ \frac{\partial R}{\partial c} &= -pF_{13}-qF_{23} & +sF_{34}, \\ \frac{\partial R}{\partial d} &= -pF_{14}-qF_{24}-sF_{34}, \end{aligned}$$

is that the coefficients on the right form a zero-axial skew array. This we may note in passing gives a self-evident proof of the known identity

$$p \frac{\partial R}{\partial a} + q \frac{\partial R}{\partial b} + r \frac{\partial R}{\partial c} + s \frac{\partial R}{\partial d} = 0.$$

It also suggests the evaluation of the inherent Pfaffian: and, following this up, we find ourselves led, by simple multiplication and repeated use of the equality $LW-MV+NU=0$, to the interesting result

$$F_{12}F_{34}-F_{13}F_{24}+F_{14}F_{23}=-NR \quad . \quad . \quad . \quad (I.)$$

5. It is, of course, not necessary to calculate independently the differential-coefficients of R with respect to p, q, r, s , as it is possible for us to utilise instead the interchange

$$\begin{pmatrix} a & b & c & d \\ p & q & r & s \end{pmatrix}.$$

Taking this course we can readily show that $\partial R/\partial p$, for example, is obtainable from $\partial R/\partial a$ by merely altering q, r, s into $-b, -c, -d$.

Our array of differential-coefficients is thus finally found to be

$$\begin{vmatrix} bF_{12}+cF_{13}+dF_{14} & -aF_{12}+cF_{23}+dF_{24} & -aF_{13}-bF_{23}+dF_{34} & -aF_{14}-bF_{24}-cF_{34} \\ qF_{12}+rF_{13}+sF_{14} & -pF_{12}+rF_{23}+sF_{24} & -pF_{13}-qF_{23}+sF_{34} & -pF_{14}-qF_{24}-rF_{34} \end{vmatrix}.$$

6. Before proceeding to consider the 2-line minors of this, it is found helpful to establish another property of the F 's, by calculating the inner product of the two rows of quantities

$$\begin{matrix} L, & M, & N, & U, & V, & W. \\ F_{12}, & F_{13}, & F_{23}, & F_{14}, & F_{24}, & F_{34}. \end{matrix}$$

As in the case of (I.) in § 4, all that is necessary is to substitute for the F 's their above-given equivalents, to perform the multiplications and to simplify, the result thus obtained being

$$LF_{12}+MF_{13}+NF_{23}+UF_{14}+VF_{24}+WF_{34}=3R \quad . \quad . \quad (II.)$$

7. Denoting now the minors of our array by $M_{12}, M_{13}, \dots, M_{34}$, we have

$$M_{12} = \begin{vmatrix} bF_{12}+cF_{13}+dF_{14} & -aF_{12}+cF_{23}+dF_{24} \\ qF_{12}+rF_{13}+sF_{14} & -pF_{12}+rF_{23}+sF_{24} \end{vmatrix},$$

which, being partitioned into nine determinants, two of which vanish, gives us

$$\begin{aligned} & (aq-bp)F_{12}^2 + (br-cq)F_{12}F_{23} + (bs-dq)F_{12}F_{24} \\ & + (ar-cp)F_{13}F_{12} + (cs-dr)F_{13}F_{24} \\ & + (as-dp)F_{14}F_{12} - (cs-dr)F_{14}F_{23} \end{aligned}$$

i.e.

$$F_{12}(LF_{12}+MF_{13}+NF_{23}+UF_{14}+VF_{24}) + W(F_{13}F_{24}-F_{14}F_{23}) :$$

and this, from using (II.) and (I.), becomes

$$F_{12}(3R-WF_{34}) + W(F_{12}F_{34}+NR)$$

and therefore equals

$$R(3F_{12}+NW).$$

By similar procedure it will be found that

$$\begin{aligned} M_{13} &= R(3F_{13}-NV), & M_{14} &= R(3F_{14}+N^2), \\ M_{23} &= R(3F_{23}+NU), & M_{24} &= R(3F_{24}-MN), \\ & & M_{34} &= R(3F_{34}+NL). \end{aligned}$$

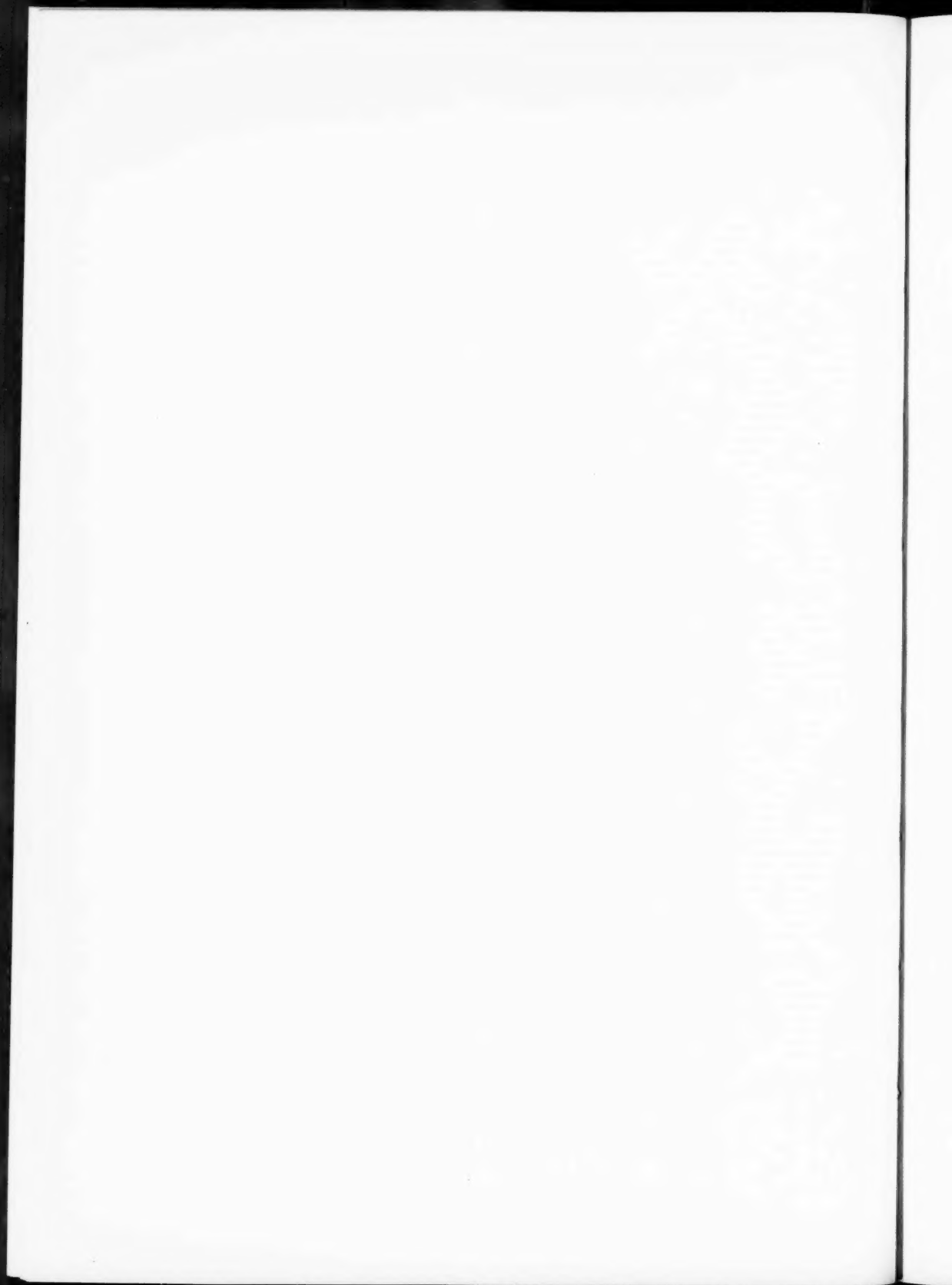
8. Not only is the theorem of § 2 thus verified, but the Pfaffian of the cofactors of R is seen to be

$3F_{12}+NW$	$3F_{13}-NV$	$3F_{14}+N^2$
	$3F_{23}+NU$	$3F_{24}-NM$
		$3F_{34}+NL$

which equals

[illegible]

RONDEBOSCH, S. AFRICA,
31st August 1929.



THE BLOOD-GROUPS OF THE BANTU.

By ADRIANUS PIJPER, M.D. (Leyden).

The importance of blood-groups for the science of anthropology is now universally recognised. The discovery of the racial distribution of the blood-groups by L. and H. Hirszfeld in 1919 is justly regarded as the greatest advance made in anthropological methods since Retzius introduced the cephalic index in 1842 (Schiff).

It is regrettable that in South Africa practically no attention has been paid to this new way of approach to racial problems. The sections of the South African population which call for investigations on these lines are the Bushmen, the Hottentots, the Bantu, and the South African Dutch. The more recent immigrants are of course of no particular interest in this connection.

The Bushmen are nearing extinction, and the racial purity of the Hottentots is becoming more doubtful every day. The need for serological investigation of these two races is quite imminent, and is well worthy of the attention of research workers who have opportunities for such an undertaking. Failing this, a small expedition, consisting of a competent ethnologist accompanied by an adequately trained biologist with a very modest laboratory equipment, could in a few weeks' time collect and investigate sufficient material before it is too late. The alternative of sending specimens from various places to a central examining laboratory is to be deprecated as interfering with the reliability of the results.

About the distribution of the blood-groups among the Bantu a short note was published by Harvey Pirie (1921), but the number of persons examined being only 250, the results, as the author himself admits, cannot be regarded as sufficient for statistical conclusions. For such purposes information about at least 500 persons is required.

I have therefore thought it worth while to extend these investigations to a larger number, and I can now report on a total number of 880 Bantu.

An investigation of the other section of the South African population which is accessible to me, and to which a certain amount of interest attaches, the South African Dutch, was started by me at the same time and is now nearing completion.*

* It has since been published, see References.

My Bantu material came chiefly from local hospitals and clinics. A small number of other natives volunteered for the test. The fact that most of my material came from hospitals and clinics will not detract from its value in the opinion of anybody who is familiar with South African conditions. As the natives originated from all over the Transvaal, I think the material can be regarded as a fair sample of South African Bantu. Efforts to establish a correlation between blood-groups and certain diseases have now failed in so many instances in various countries that no valid objection can be raised against material such as I have used.

TECHNIQUE.

Schiff (1926) called the test-tube method the method of choice, and therefore all my reactions were done in test-tubes. One or two drops were obtained from every individual through pricking a finger, and caught in a small test-tube containing one cubic centimetre of 0.9 per cent. sodium chloride with 0.5 per cent. sodium citrate. The reaction was then performed within a few hours by mixing two drops of the test serums (A and B) with four drops of the chromocyte suspension in special narrow test-tubes. Readings were taken by two persons independently after a few hours. The tubes were kept in an underground room where a constant temperature of 20° prevailed winter and summer.

Test serums were made on the spot from the blood of previously tested persons. A preliminary cross-agglutination between the serums and cells of a dozen persons had led to a provisional assignation of blood-groups amongst these twelve. One person of the provisional A group was then retested at the Lister Institute in London by Dr. H. Schütze (to whom I here offer my thanks), and the provisional result was confirmed. In this way the selection of persons to serve as sources of A and B serum was put on a safe basis, and the blood of this person was used throughout the whole course of the investigations as a control every time new test serums were prepared. Only such serums as gave clear-cut results were employed. All serums were used fresh, without the addition of chemical preservatives. I think this method is preferable to the use of imported commercial serums of unknown age and activity.

RESULTS.

The results are given in the most concise form in Table I. Although in most cases one got the impression that the tribe of the individual could be ascertained with a reasonable degree of accuracy, too much value should not be attached to this aspect. It will be seen that most of the natives examined called themselves Basutos. The results of the examination of the small

number of persons representing other tribes is given separately for the sake of completeness, not because they are supposed to reveal anything specific for these tribes.

TABLE I.
Bantu Blood-groups.

Tribe.	Num- ber exa- mined.	O.		A.		B.		A B.		Index.
		Num- ber.	Per cent.	Num- ber.	Per cent.	Num- ber.	Per cent.	Num- ber.	Per cent.	
Basuto .	705	368	52.2	187	26.5	135	19.1	15	2.1	1.3
Matabele .	64	31		14		16		3		
Shangaan.	47	31		9		7		0		
Zulu .	22	11		7		4		0		
Swazi .	14	11		2		0		1		
Kosa .	13	7		2		4		0		
Bavenda .	8	5		1		2		0		
Baralong .	7	4		1		1		1		
Total .	880	468	53.2	223	25.3	169	19.2	20	2.3	1.3

DISCUSSION OF RESULTS.

A comparison of my results with those of others dealing with similar and allied groups of dark races is given in Table II (p. 314). This table comprises all that at the present moment is known about African natives and their descendants.

The significant features of this table are :

1. That the Negroes of Africa have an index below 1.
2. That their descendants in America have an index of 1.3.
3. That the South African Bantu have an index of 1.3.

Although the table also contains results of examinations performed on rather too small a number of individuals, it will be noted that these three important features result from the examination of a sufficiently large number of cases to place them beyond reasonable doubt.

That the index of the American negroes has risen from the original 0.8 to 1.3 is of course due to the pretty large admixture of white blood which has taken place in America. It is estimated that at least one-third of American negroes have some white blood (Lewis and Henderson).

TABLE II.

Author.	Race.	Number examined.	Groups in percentages.				Index.
			O.	A.	B.	A B.	
L. and H. Hirszfeld.	Senegalese .	500	43.2	22.4	29.2	5.0	0.8
Bruynoghe and Walravens.	Katanga. Belgian Congo }	500	45.6	22.2	24.2	8.0	0.9
Müller .	West Africa.	325	52.3	21.5	23.0	3.2	0.9
Lewis and Henderson.	American negroes.	270	49.0	26.9	18.4	5.5	1.4
Snyder .	American negroes.	500	47.0	28.0	20.0	5.0	1.3
Pirie .	Bantu .	250	52.0	27.2	19.2	1.6	1.4
Pijper .	Bantu .	880	53.2	25.3	19.2	2.3	1.3
L. and H. Hirszfeld.	Arabs .	500	43.6	32.4	19.0	5.0	1.5
Altounyan .	Arabs .	933	36.0	37.0	21.0	6.0	1.6

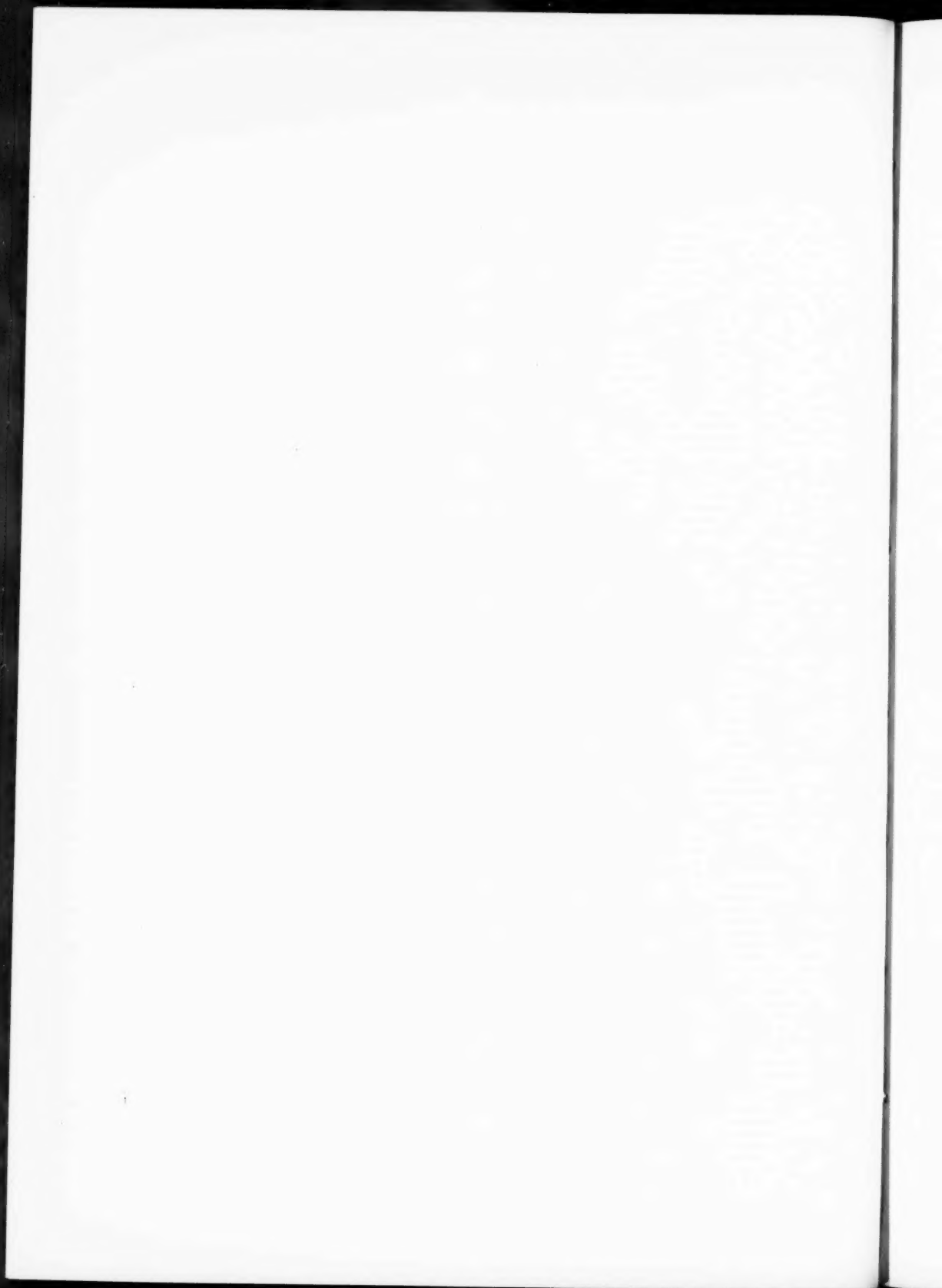
The striking difference in index of the Bantu and the Negroes cannot be explained in this way. Apart from a few historical curiosities there is no evidence at all that there ever has been an infusion of white blood into the ancestors of the Bantu. Such a possibility can definitely be ruled out.

It therefore remains all the more significant that the Bantu are the only native race of Africa of which we know that it has such a curiously high index. It is higher than that of the mixed races of Egypt, which was put at 1.07 (Shousha), and it very closely approaches that of the Arabs and the Jews.

The current belief about the origin of the Bantu is that they are of Negro origin (Dart), with perhaps a slight admixture of Hamitic blood. My figures of the distribution of blood-groups make such views untenable. Whatever may have been the exact index of this Hamitic blood, it will not have been much higher than 1.5. A large infusion of white blood with an index of at least 3 has only succeeded in raising the original Negro index of 0.8 to 1.3 in America. It is therefore inconceivable that a slight admixture of Hamitic blood with an index of about 1.5 would have raised the Negro index from 0.8 to 1.3. The facts of the matter definitely point the other way: the Bantu have to be looked upon as direct descendants of the Hamitic race, with perhaps a very slight admixture of Negro blood.

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LIVING HUMAN BLOOD CELLS UNDER THE DARK-GROUND MICROSCOPE.

By JOHN H. FERGUSON, B.A. (Oxon. and U.C.T.), M.D. (Harvard).

(With Plates IV.-VIII.)

INTRODUCTION.

For a long time the study of living cells under the highest powers of the microscope has taken second place to observations on fixed and stained cells. This has led to a vast accumulation of data—often inconclusive—upon which diverse and frequently conflicting theories of cell-structure and cell-function have been based. With the advent of intra- and supra-vitam staining methods, and of tissue-culture and other experimental cytological procedures, the attention of careful observers is being refocussed upon the examination of the living cell in the search for critical evidence to support the various theories. The dark-ground microscope has been in use for a number of years and has been employed in cytological observations, but we are of opinion that its value as a critical method has yet to be realised. Given the requisites :

- (i) a good dark-ground microscope ;
- (ii) the maintenance of cells in a controlled environment—*e.g.* a warm chamber—so that normality can reasonably be granted ;
- (iii) comparative observations with ordinary fixed (dead) and stained cells,

we may establish data of definite value as the following record of some observations on living human blood cells shows.

LIVING HUMAN BLOOD CELLS.

When a drop of freshly drawn human blood is placed on a scrupulously clean slide under a cover-slip and examined in a Hearson warm chamber at body temperature (37° C.), using the "dark-ground method" of illumination, the "formed elements" of the blood are easily studied in the living state, even with the highest powers of the microscope. A certain degree of abnormality of the cell environment will result from drying, loss of gases,

alteration of salt, and pH concentration, and of the delicate protein, lipoidal, and other colloidal equilibria, in the plasma (as evidenced by "clotting"), and eventually in the cells. These changes in themselves are interesting material for study. However, the fact that the leucocytes manifest continuous motility, phagocytic powers, and other evidence of functional activity, often for many hours, indicates that the environment is not seriously altered in respect of the factors influencing the vitality of these cells. Furthermore, the effects of these environmental changes are often definite and enhance the value of certain observations, as will appear in the sequel. Then again, simple variations of the experimental conditions readily suggest themselves.

MORPHOLOGICAL ELEMENTS SEEN IN BLOOD UNDER THE DARK-GROUND MICROSCOPE.

- A. The *Blood Plasma* shows numerous refractile dots dancing vigorously in Brownian movement. These are indicative of the colloidal nature of certain elements in the plasma. "*Haemokonion*" may be noted.

Fibrin Crystals may be observed to separate out during "clotting" as fine, slightly refractile needles, as Howell originally described.

The *Blood Platelets* provide such material for study by this method that we intend devoting further attention to them in a subsequent communication.

- B. The *Red Blood Cells* show their well-known morphological appearances, viz. biconcave discs liable to crenation, haemolysis, and the formation of *demi-lune* bodies. *Nucleated* red cells of amphibia and of mammalian embryos show a small feebly refractile nucleus in the fluid-like non-refractile contents of the haemoglobin-containing cell.
- C. The *White Blood Cells* are exceptionally well studied by the dark-ground method and constitute the chief object of inquiry in the present communication. The five classical varieties of leucocyte may be recognised easily after a little practice.

POINTS STUDIED UNDER THE DARK-GROUND MICROSCOPE.

The points of difference may be dealt with under the following heads :

- I. Nuclear detail.
- II. Cytoplasmic detail.
- III. Type of movement.
- IV. Phagocytic powers.

I. *Nuclear Detail*.—The relatively non-refractile nucleus exhibits typical features as regards size, shape, and position in cell. Its degree of polymorphism is retained through all extremes of amoeboid distortion of the cell.

The nuclear membrane and intra-nuclear elements become somewhat more refractile in older preparations and show details of some descriptive value.

Nucleoli are conspicuous in "young" cells, *e.g.* in myeloid leukaemia.

II. *Cytoplasmic Detail*.—Shape and size are unimportant as compared with stained films. The non-refractile hyaloplasm is well seen in the pseudopods, etc., during amoeboid movement, its margins being feebly refractile and often thrown into delicate folds. The leucocytes contain:

- (1) *Granules* of varying, and, to some extent, "specific" refractility. Their oscillatory (Brownian) movements, even in the resting cell, point to the fluidity of the cytoplasm. They show a streaming motion in moving cells.
- (2) *Mitochondria*—delicate, fairly refractile, wriggling, rod-like, or filamentous bodies best seen in the large mononuclears and lymphocytes.
- (3) *Vacuoles*—rounded non-refractile "holes" in the cytoplasm, occasionally present, especially in neutrophils, eosinophils, and large mononuclears.
- (4) *Cytoplasmic Inclusions*—*vide* Phagocytosis.

III. *Type of Movement*.—All five varieties of leucocyte exhibit active amoeboid motility. The polymorphs—neutrophil, eosinophil, and basophil (in this order)—are continuous in their display of wandering properties, and never really rest until abnormal changes begin to set in. In contrast, the mononuclears—monocytes and lymphocytes (especially the latter)—are intermittent in their wanderings, often "resting" for prolonged periods, merely exhibiting local change in form, while at other times they become "active" and wander over considerable distances.

IV. *The Phagocytic Powers* of leucocytes for refractile materials such as yeasts may be studied under the dark-ground microscope.

The differences between the five types of leucocyte appear in tabular form at the end of the paper.

REGRESSIVE CHANGES IN LEUCOCYTES.

Under prolonged observation certain cytological changes occur which may be attributed to the influence of the altered environment. These may

be grouped as "regressive changes." They may be described in the instance of the neutrophil polymorph as follows:—

The nuclear detail and ectoplasm become more distinct than at first, but for a considerable time the cell exhibits full amoeboid activities. After some hours there is a tendency for longer and more filiform pseudopods to develop, these often forming a trailing tuft. Movements, in time, become more sluggish and less continuous. Wandering ceases and the cell exhibits mere local changes in form, with apparently purposeless pseudopod protrusion. It then rounds off gradually and the ectoplasm becomes more distinct. The granules until now have continued in active streaming and oscillation, but subsequently they slow down and lose first their streaming movement and then their oscillation. The latter is preceded by a stage in which the granules exhibit a jerky movement, especially visible at the surface of the cell, where they may be seen to shoot out spasmodically in a streamer of ectoplasm which again pulls them back into the cell. They cease to move in certain parts of the cell, and it seems as if a paralysis is creeping over the whole cytoplasm until all is involved and the last particle becomes motionless.

After some hours it is noted that the majority of leucocytes have become reduced in size, and little granular fragments of protoplasm may be seen lying about. That these are indeed fragments of leucocytes is clearly indicated in a number of our observations. We have noted the early surface-tension changes that lead to the formation of filiform trailing pseudopods. These seem to show a certain "stickiness" as judged from the manner in which they can adhere to red cells, etc., and drag them along in the wake of the leucocyte. In contact with platelets this "stickiness" is even more marked, and may anchor the hinder end of the leucocyte to a platelet clump, and lead to a drawing-out of the cytoplasm as the cell tries to move off. On several occasions we have observed the polymorph to break away with the loss of a portion of its cytoplasm. The lost portion of the cell, containing hyaloplasm and granules but no observed nuclear material, behaves in a manner that recalls Chambers' and Kite's microdissection experiments. It first exhibits an independent amoeboid motility resembling that of the parent cell. Soon, especially if it remains anchored, its attempts at wandering cease, and it undergoes exactly similar regressive changes to those described above for the whole cell, showing especially well the agonal jerkiness of the granule oscillations.

These phenomena are undoubtedly connected with "surface-tension" changes both at the margin of the cell and in its "milieu interne," and they strongly favour the theory of a "sol" colloid of living protoplasm being converted into the "gel" form during the death of the cell.

CONCLUSIONS.

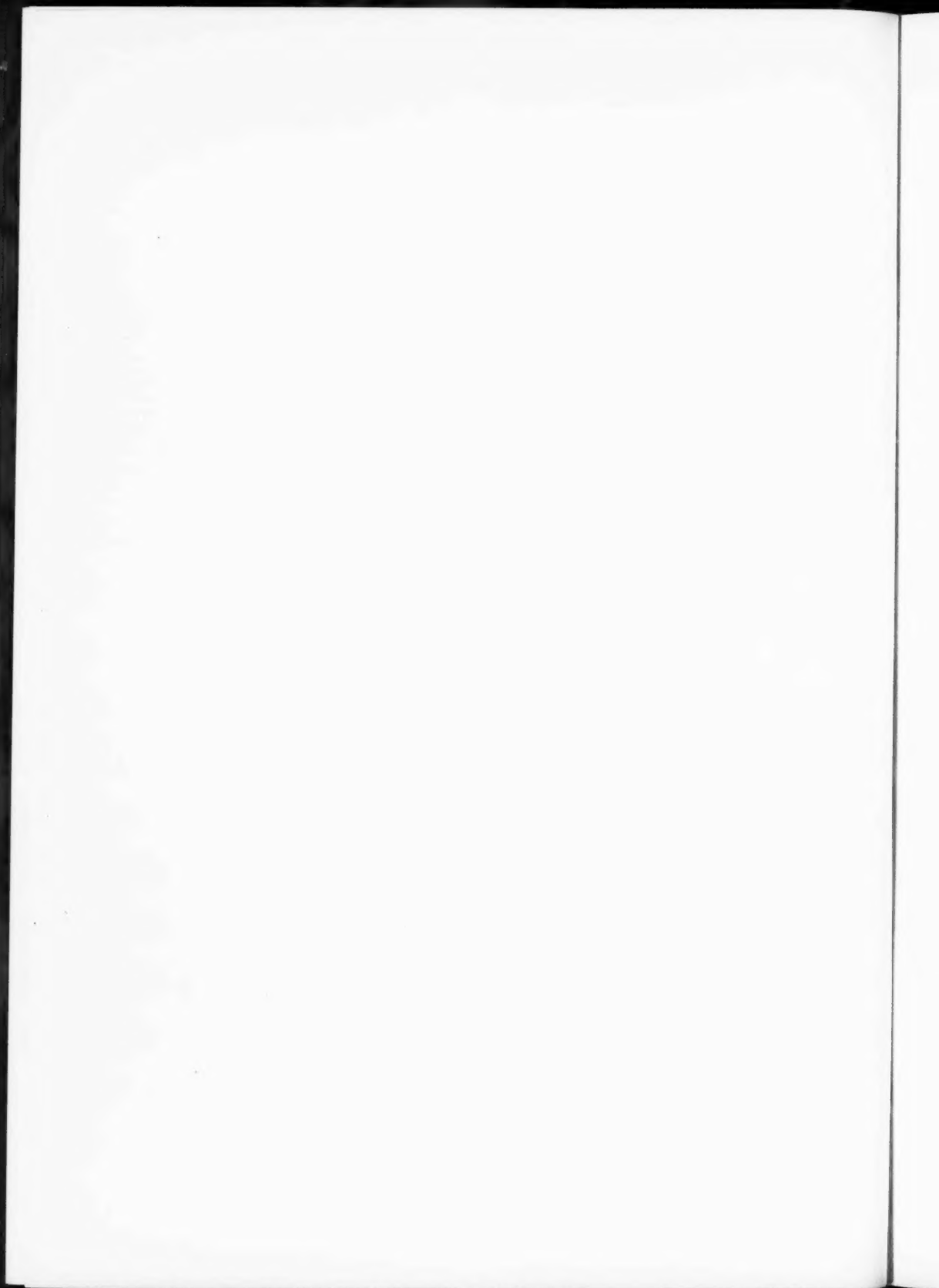
These preliminary observations are not concerned with a truly comparative study of the blood cells—which would utilise the blood of amphibia, birds, and mammals other than man—nor with the morphogenesis of these cells as judged from observations on embryonic material, films from the haemopoietic organs, and human blood in the leukaemias and other diseases. They serve to demonstrate, however, a wide field of investigation that may be explored under experimental conditions which preserve to a gratifying extent the essential vital characters of living body cells.

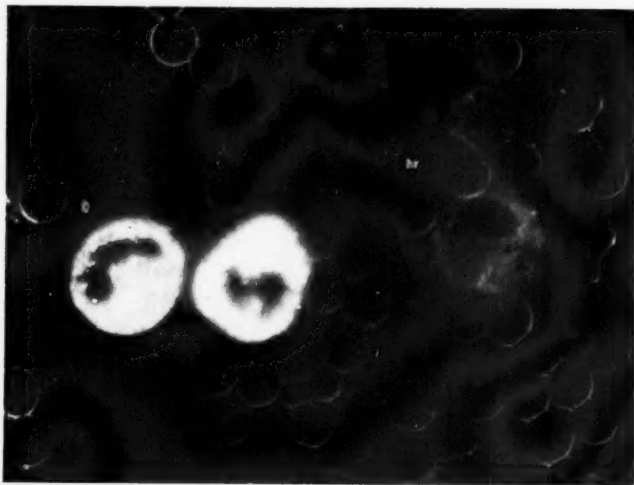
Our thanks are tendered to the University of Cape Town Research Grant Board for funds which have been available for the obtaining of photographic and other materials for these investigations.

[TABLE.]

Features of	Neutrophil polymorph.	Eosinophil.	Basophil.	Large mononuclear (including Ehrlich transitional).	Lymphocyte (small and large).
<i>Nucleus.</i>	Easily seen: polymorphic to a varying extent, averaging 3-4 lobes.	Easily seen: more or less polymorphic, averaging 2 lobes.	Quite easily seen: generally rounded, oval, or reniform, may be polymorphic.	Often difficult to see at first: typically ovoid, reniform, or horse-shoe shaped (Ehrlich's transitional cell).	Easily seen: typically rounded; frequently with a deep slit or indentation of inconsistent form.
Nuclear membrane.	Not very distinct at first, but becomes more so later.	Not very distinct at first, but becomes more so later.	More distinct than in neutrophil and eosinophil.	Not distinct, but improves later.	Usually quite definite, especially later.
Intra-nuclear detail	(Especially evident later) — irregular rings of slight refractility, especially situated next to the nuclear membrane; apparently united by a poorly refractile meshwork.	(Especially evident later) — similar to neutrophil.	(Especially evident later) — similar to neutrophil and eosinophil.	(Especially evident later) — finer and more irregular pattern, often with a few slightly refractile rings of slightly irregular outline (γ = "nucleoli").	(Especially evident later, but also good at first) — very fine granular-looking pattern, suggesting an exceedingly fine, irregular meshwork.
<i>Cytoplasm.</i> Ectoplasm	Not very conspicuous at the height of amoeboid activity, but often clearly seen as an outflowing mantle or as trailing pseudopods.	" " "	Conspicuous owing to paucity of granules.	Very delicate but often abundant and conspicuous, flowing out in wavy mantles and forming fine filiform pseudopods in all directions.	Scanty, but conspicuous owing to paucity of granules: wavy mantles common; sometimes fine filiform pseudopods in all directions.
Granules	Very actively oscillating: brightly refractile: silvery in colour: fairly large: even in size: numerous and crowded.	Actively oscillating: very brightly refractile: golden in colour: relatively large: even in size: numerous and crowded.	Fairly actively oscillating: few in number on the whole, usually a sparse arrangement of large granules: bright, but less so than in eosinophils; with a number of fine, small granules, most of the hyaloplasm, however, looking "empty."	Oscillating, with variable speed and amplitude: considerable variation in size and intensity: usually the majority are small and hazy; but there are a few largish scattered brighter granules.	Oscillating, usually with small amplitude: mostly small hazy granules, but typically there is a cluster of brighter granules tending to gather at one side (especially in the hollow of the nucleus).

Mitochondria.	Rarely visible owing to granules, but have been seen as little wriggly rodlets in the stretched-out hyaloplasm.	? (Not observed).	? (Not observed).	Often well seen as rodlets, filaments, or strings of granules: especially around nucleus or in hollow of it.	Sometimes well seen: moderate numbers: appearances similar to those in monocytes.
Vacuoles	Small non-refractile round bodies: rare: generally single.	Rarely observed.	? (Not observed).	Not infrequent: small: one or more may be present.	? (Rarely observed).
Motility.	"Continuous": very actively amoeboid, typically with a mantle of ectoplasm preceding, the granules soon following, and the nucleus in the rear: blunt granular pseudopods may develop in any direction: sometimes the cell is seen in two portions, united by a stretched-out band of hyaloplasm (perhaps containing a filament of nucleus): when movement is more sluggish, clear, ectoplasmic pseudopods are more frequent and may form a tuft of trailing, filiform processes.	"Continuous": character of motion identical with that of neutrophil.	"Continuous" as a rule: sometimes less marked: character of motion identical with that of neutrophil and eosinophil.	"Intermittent," especially at first, but in older preparations (when polymorphs are slowing down) it becomes continuous for long periods: character of motion —not unlike polymorph, but speed varies greatly, and is often slower with more and finer pseudopods, trailing and otherwise.	"Intermittent," with long resting periods in which only movements are change in shape of nucleus, protrusion of mantles and pseudopods of ectoplasm, and slight flowing of granules: during spurts of activity the cell may elongate into a dumb-bell or hour-glass shape: but is usually pyriform with a mantle of ectoplasm preceding, followed by the nucleus, then the clump of bright granules at the base of the blunt trailing pseudopod: filiform pseudopods develop when activity is less marked.
Phagocytosis of yeasts.	Actively phagocytic.	Quite actively phagocytic.	? (Not observed).	Actively phagocytic.	? (Not observed).

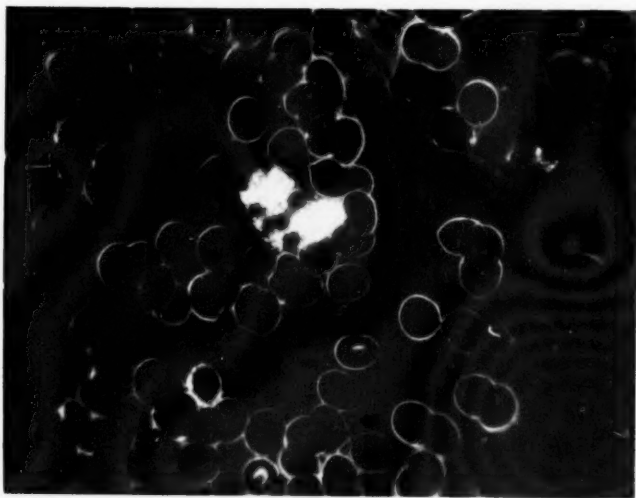




Human leucocytes, photographed under the dark-ground microscope.

Note.—Degrees of refractility.

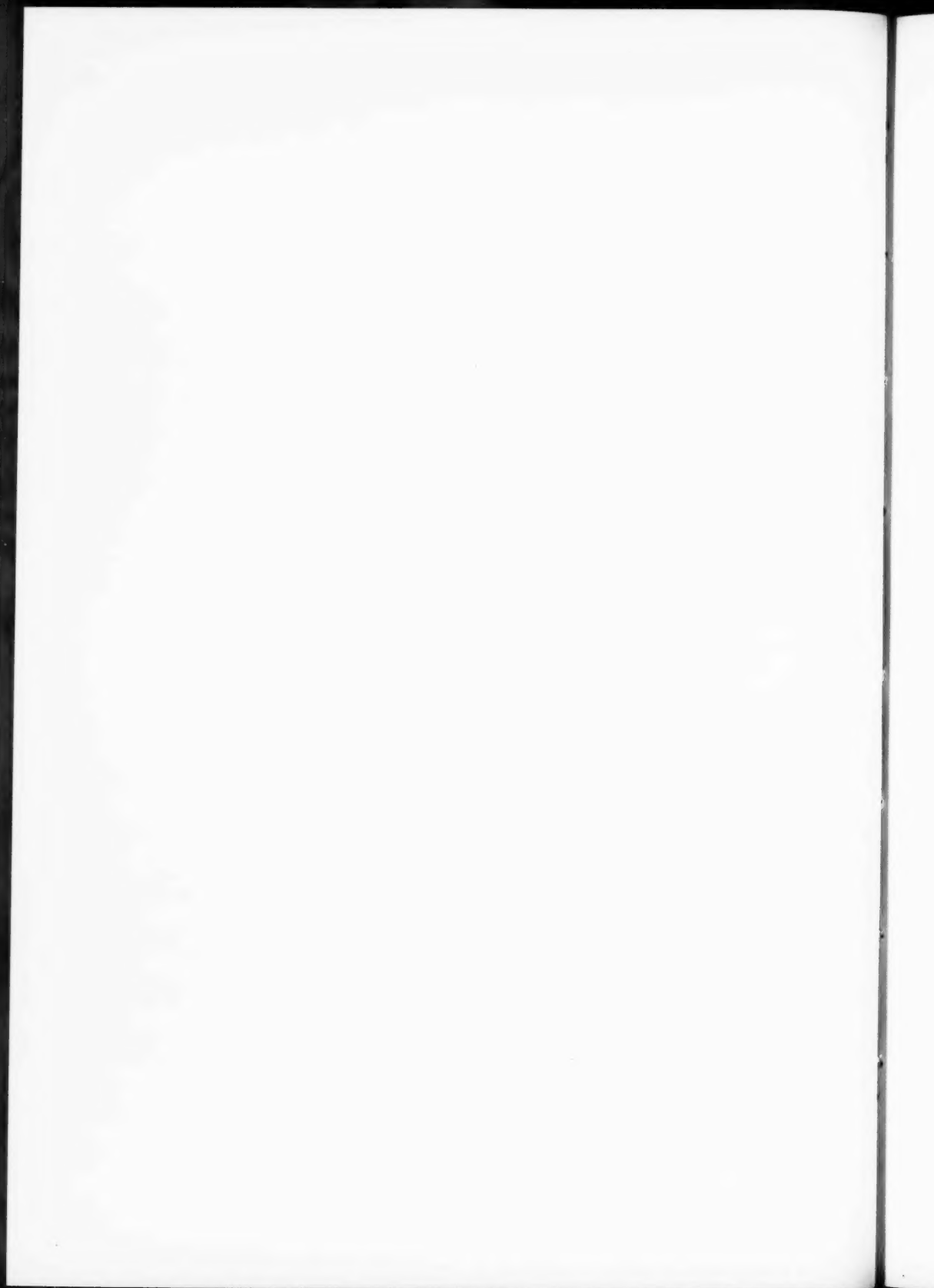
FIG. 1.—Neutrophil(e) polymorph; eosinophil(e) polymorph; large mononuclear lymphocyte. $\times 1200$.

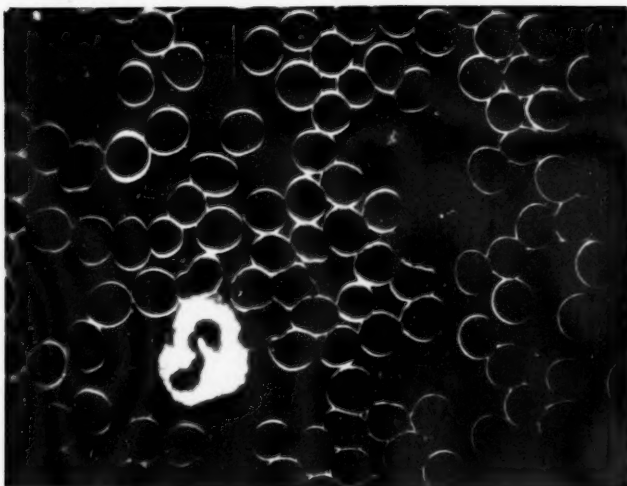


Neutrophil(e) polymorphonuclear leucocyte.

Size, $13\ \mu$. Constitutes 55–65 per cent. of human white blood cells.

FIG. 2.—Under dark-ground illumination. $\times 1000$.





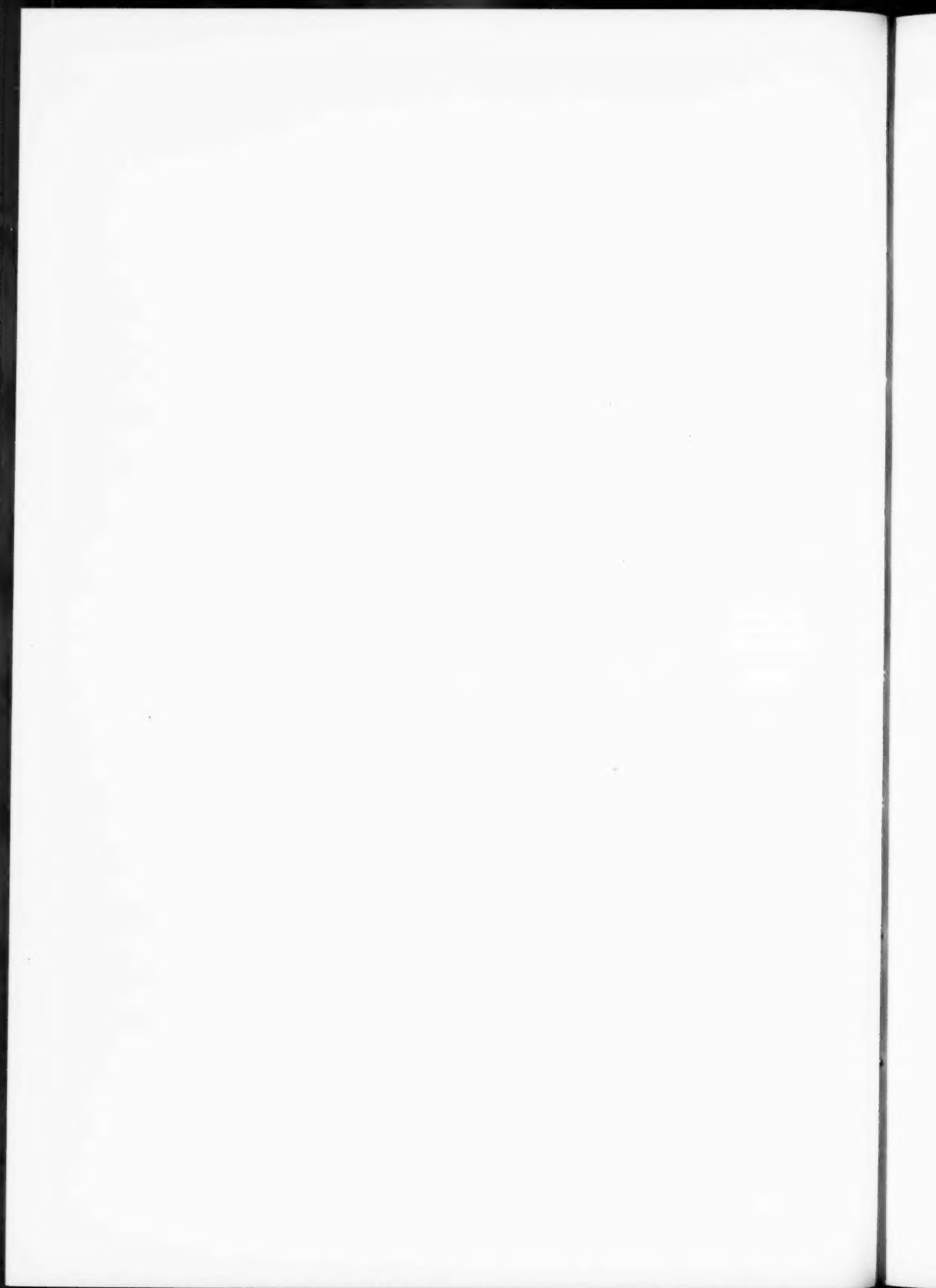
Eosinophil(e) polymorphonuclear leucocyte.
Size, $12.5\ \mu$. Constitutes 1-3 per cent. of human white blood cells.

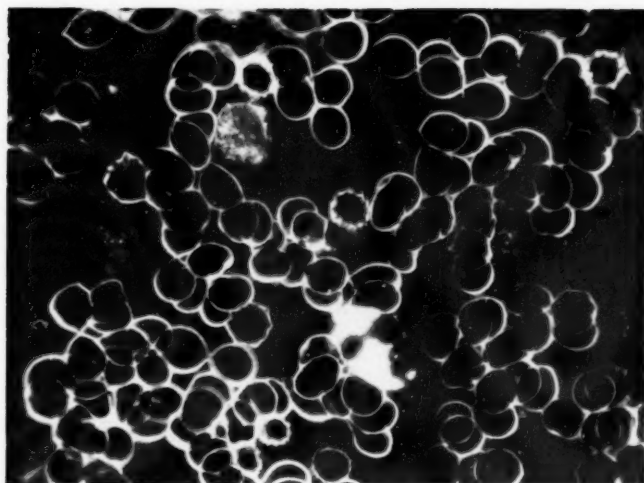
FIG. 3.—Under dark-ground illumination. $\times 1000$.



Basophil(e) leucocyte or mast-cell.
Size, $12\ \mu$. Constitutes less than 1 per cent. of human leucocytes.

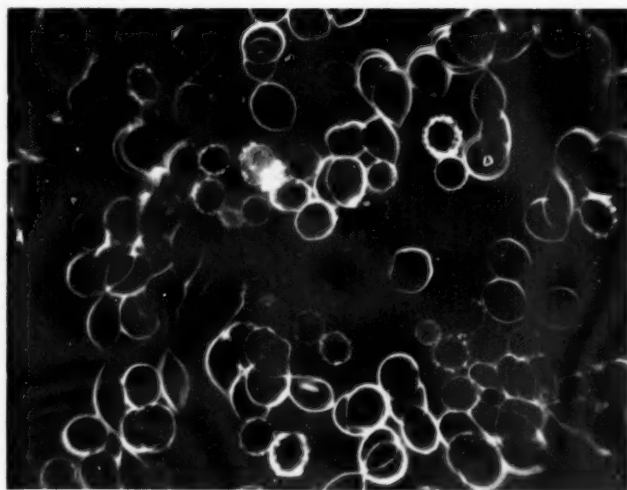
FIG. 4.—Under dark-ground illumination. $\times 1200$.





Large mononuclear leucocyte (monocyte).
Size, 18μ . Constitutes 2-6 per cent. of human white blood cells.

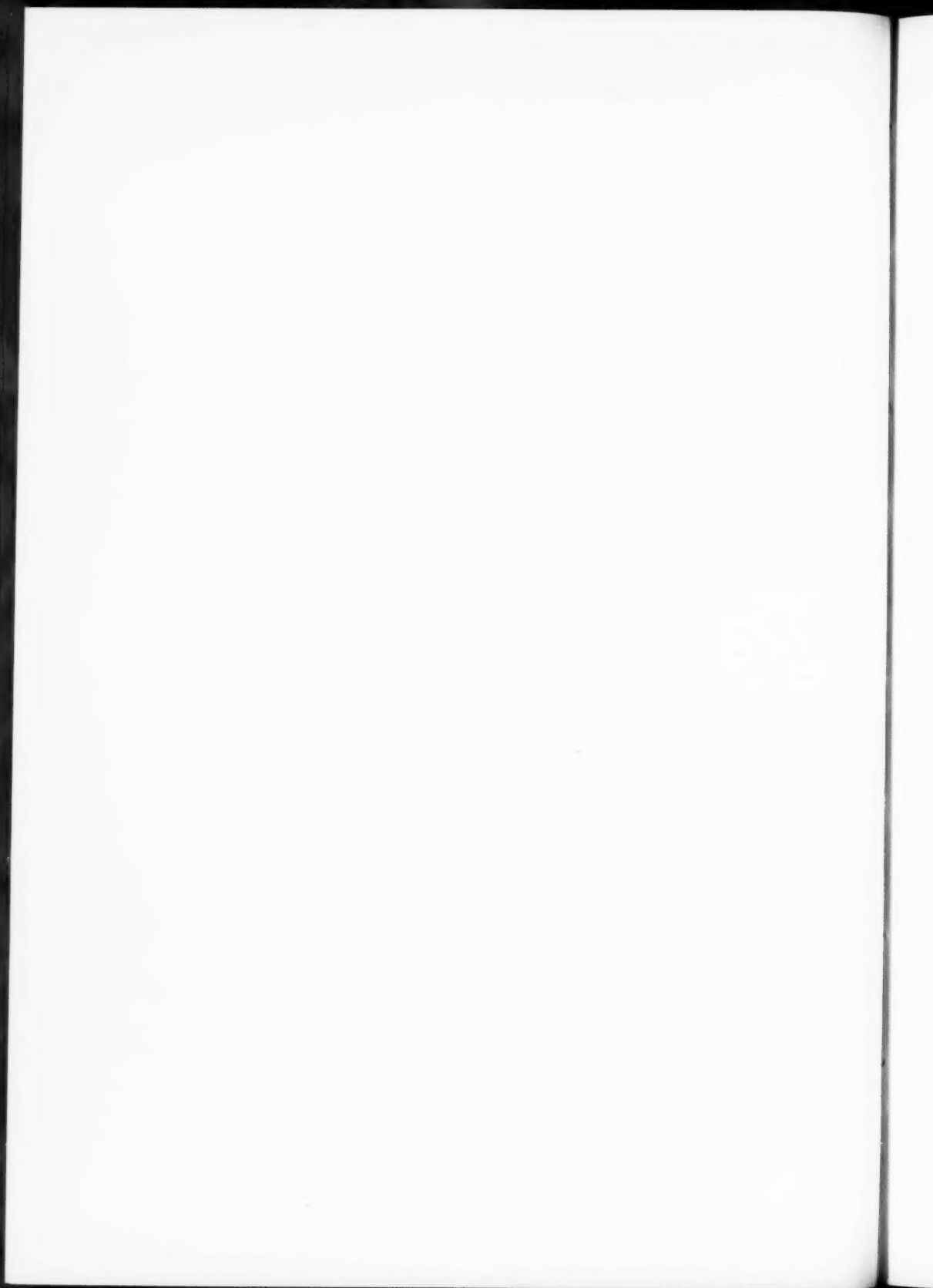
FIG. 5.—Under dark-ground illumination. $\times 1000$.
(Also included eosinophil(e), with granules in motion.)



Small lymphocyte.

Size, 9μ . Constitutes 20-30 per cent. of human white cells.

FIG. 6.—Under dark-ground illumination—lymphocyte at rest, showing bright granules. $\times 1000$.



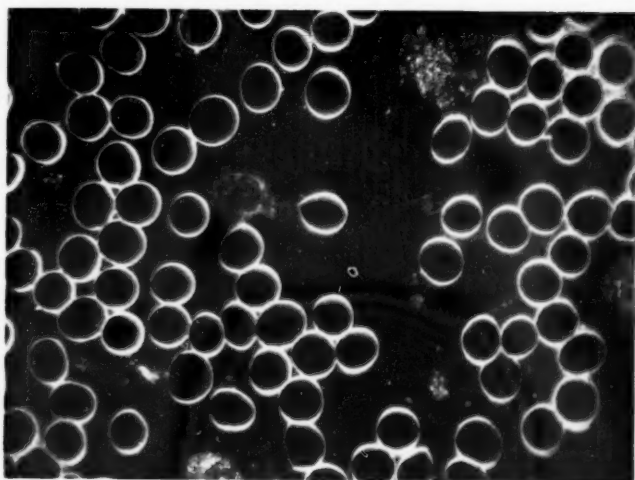
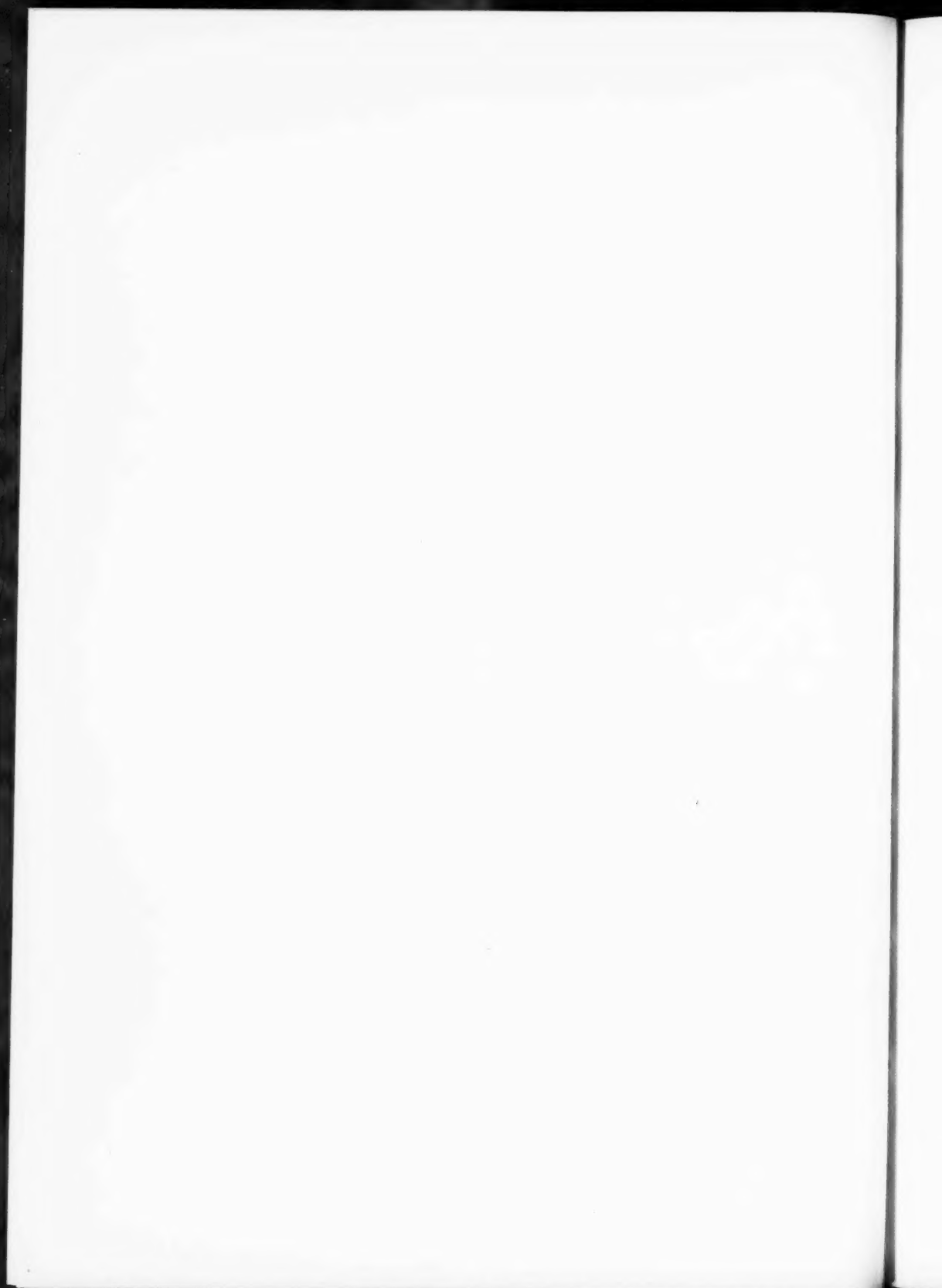


FIG. 7.—Under dark-ground illumination—lymphocyte in motion with trailing pseudopod. (Also included (a) fibrin "crystals"; (b) blood platelets, with "excrescences.") $\times 1000$.



Moving white blood corpuscles, photographed under the dark-ground microscope.

FIG. 8.—Neutrophil(e) polymorphonuclear leucocyte. $\times 1200$.



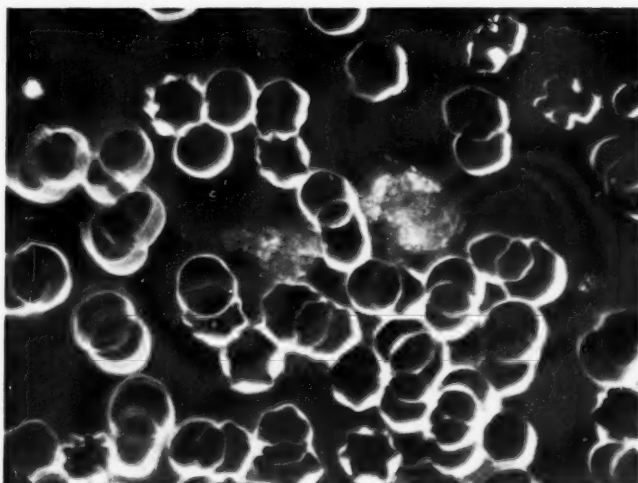
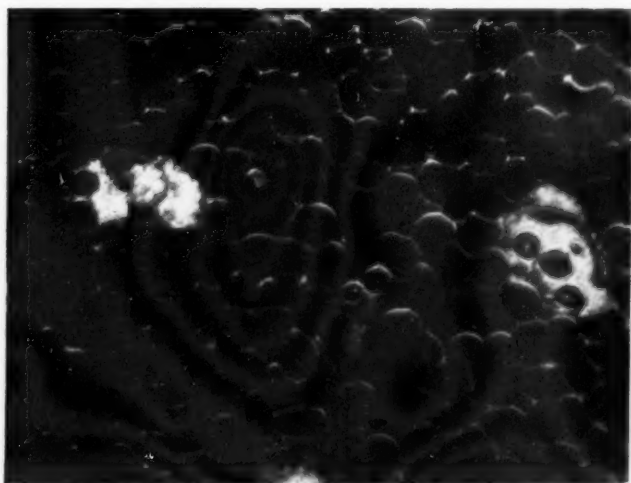


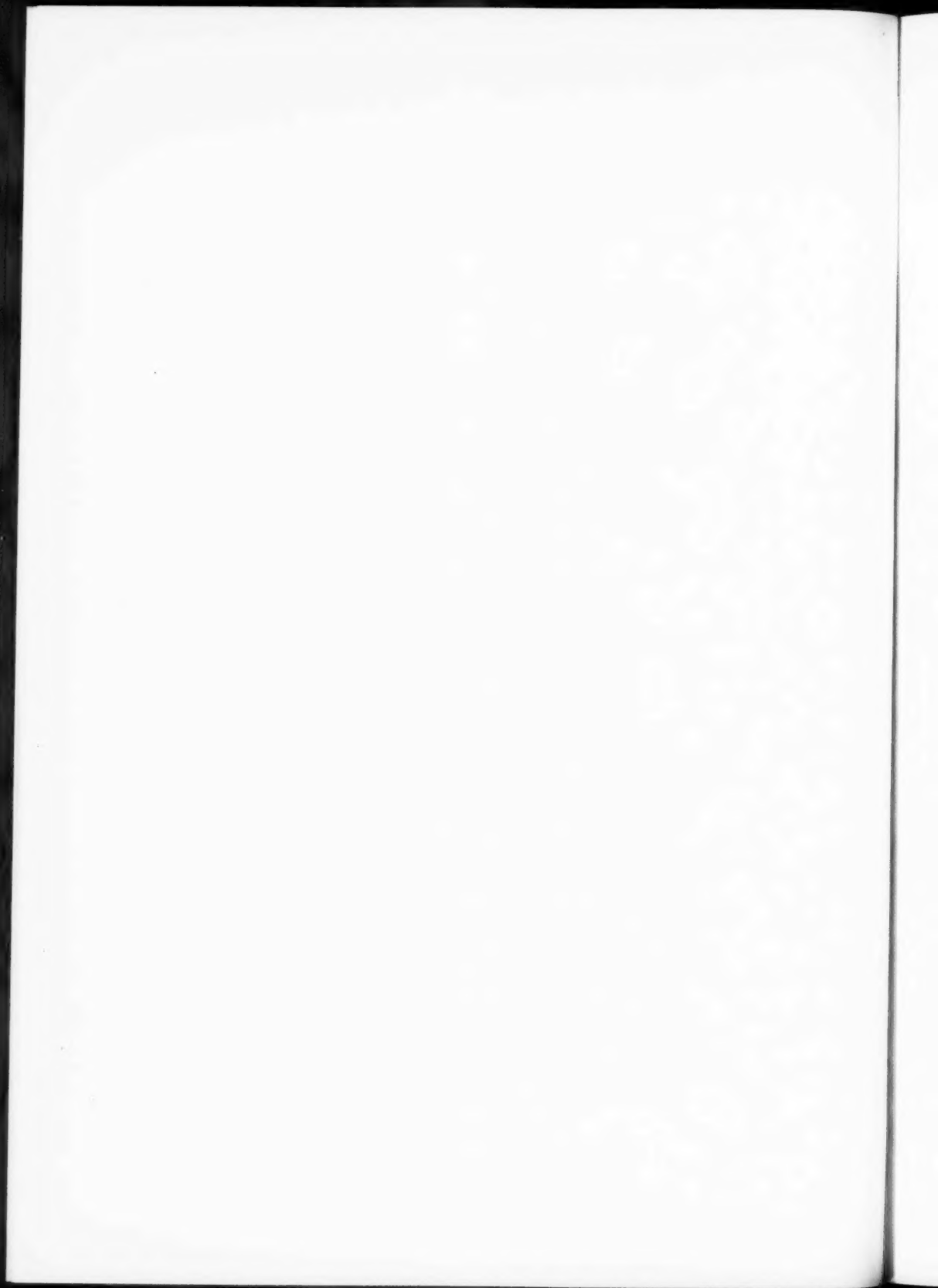
FIG. 9.—(a) Lymphocyte—note trailing "pseudopod"; (b) large mononuclear cell—note filiform "pseudopodia."



Phagocytosis of Yeasts by living human leucocytes.

Dark-ground illumination.

FIG. 10.—Eosinophil, to the left of the photo-micrograph; neutrophil, to the right of the photo-micrograph; lymphocyte, in centre, has not ingested the two adjacent torulae. $\times 1300$.



SOME OBSERVATIONS ON THE EMBRYONIC RADULA
OF *LIMNAEIDAE*.

By F. G. CAWSTON, M.D.

In most of those species of the *Limnaeidae* which I have examined the adult radula consists of about 120 to 150 rows of teeth, there being one central tooth, seven to nine laterals, and from ten to twenty marginals on either side in each row. At the time of hatching there are about 500 teeth in the radula, but the number rapidly increases until the adult mollusc possesses from 7000 to 10,000 teeth.

The central tooth of each row is clearly recognised by its narrow plate and crown. As the base is somewhat expanded, the plates of the laterals and marginals are rendered oblique. The central tooth of *Physopsis*, *Bulinus*, and *Planorbis* possesses a well-expanded base, so that the laterals and marginals are rendered more oblique than those of *Limnaeae*. The central tooth of *Limnaea natalensis* Krauss is small and narrow and usually possesses but one cone or cusp.

In its earliest stage of development the radula appears as a crescentic ridge. Well before the embryo hatches it is possible to differentiate the three varieties of teeth. The tricuspid laterals are the first to form, and in the youngest embryos only laterals are visible at the extreme anterior end of the radula. It is impossible to define cones in the central tooth of the front rows of the embryonic radula; but those of the central and posterior rows show well-defined cones, as do the lateral teeth in most of the rows. With care one can observe the prolonged and divided cones of the marginal teeth before hatching takes place. The individual embryonic teeth can be separated from one another, and the plate, the crown of the tooth, and the cones which grow from it, more carefully studied. The embryonic radula is clearly visible under a third objective, but it is necessary to use a sixth to study the teeth in detail. The radula is easily seen when an egg, almost ready to hatch, is squashed between a stout cover-glass and a microscopic slide. With adult examples I have obtained good results by allowing the animal to slightly decompose for twenty-four hours, and then to separate the buccal mass and compress it between two glass slides. Having separated the radula, I have allowed it to dry on the slide, cleansed it with water, and added a few drops of caustic soda or ether before compressing it under a

cover-slip. Glycerine jelly is the best preservative for radulae, as Canada Balsam renders the teeth too transparent. There is very little risk of breaking the teeth of *Limnaeidae*, though the cusps of *Melanoides tuberculatus* are easily bent back from their normal overhanging position. The best models are cut out of sheet lead and coated with white vulcanite, after being shaped over the usual *camera lucida* sketches.

Occasionally the endocone and mesocone of lateral teeth are partially united; much less commonly it is the ectocone and mesotone. There is a certain degree of variation in the cone-formation at various parts of the same radula and in individual examples of the same species.

The marginals are characterised by numerous denticles or cones. In the youngest embryonic radulae the tips of the denticles lie in a straight line; but in the adult the denticles suggest the appearance of a cat's claw or the human hand. The typical marginal tooth of an adult radula possesses four to six finger-like denticles, one thumb-like denticle, and two small spur-like denticles.

When about to hatch, the embryonic radula measures 0.1 mm. in length. The lateral tricuspid teeth are the most prominent and are seen to consist of a well-developed plate already 0.01 mm. high, capped with an overhanging ridge which is to form the crown of the tooth, from which the cones grow. The marginals are not very well defined in the embryonic stage; but they rapidly increase in number once hatching has taken place. There are fewer teeth in the front rows, and these front rows are bent back in the embryonic radula as is constant in the mature radula.

During the next few days after hatching has taken place there is an increase in the number of rows of teeth and in the number of teeth in each row. The absence of cone-formation in the anterior portion of the radula persists and is associated with the fact that the anterior extremity, by being bent back slightly, avoids the full force of the coarse surface of food, a large surface of which is covered by the broad radula of *Limnaeidae*.

These conclusions have been reached by a careful study of numerous examples of *Limnaea natalensis* Krauss, *Limnaea stagnalis* Linnaeus, *Limnaea peregra*, *Limnaea palustris*, *Limnaea truncatula* Müller, *Physopsis africana* Krauss, *Physopsis globosa* Morelet, *Bulinus tropica* (Krauss), *Bulinus forskali* (Krauss), *Planorbis pfeifferi* Krauss, species of *Burnupia*, *Ferrissia*, *Gundlachia*, and allied species.

REFERENCE.

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SOME PHACOPIDAE FROM THE BOKKEVELD SERIES.

By JOHN V. L. RENNIE, M.A., Ph.D.

Department of Geology, University of Cape Town.

(With Plates IX, X and one Text-figure.)

The following notes are, in part, the outcome of a visit paid in 1928 by Dr. L. D. Boonstra and the writer to the well-known locality Gamka Poort, on the northern flank of the Zwartbergen. Here the Phacopidae, most frequently preserved as moulds and casts in dark-coloured nodules, are the most conspicuous element of the fauna of the First or Basal Shales which form the lowest lithological subdivision of the Bokkeveld Series (Lower Devonian). Prolonged search resulted in the recovery of a fine series of specimens, some of them unique, and it is desirable that the new data made available by this collection should be placed on record.

A large proportion of the Bokkeveld species has been erected on very incomplete or badly preserved specimens, and as the work of determination of the new material proceeded, it became evident that (1) some of the older species would have to be regarded as specifically indeterminable, and that (2) certain forms hitherto regarded as distinct would have to be placed in the same species. It was found necessary to define, by fixation of the genotypes, the groups *Anchiopella* Reed, *Eocorycephalus* Reed, and *Metacryphaeus* Reed. Moreover, the writer found himself unable to agree entirely with the classification of the family used by Reed in his "Revision of the Fauna of the Bokkeveld Beds" (1925b) and his "Recent Work on the Phacopidae" (1927), and was led, after a critical review of the available evidence, to accept a classification akin to that adopted by Kozłowski (1923).

The writer has examined the bulk of the Bokkeveld type material, and is greatly indebted to Dr. S. H. Haughton for enabling him to see material preserved in the South African Museum, Cape Town, the Albany Museum, Grahamstown, and the McGregor Memorial Museum, Kimberley; to Dr. S. J. Shand for permission to see material in the Department of Geology, University of Stellenbosch; to Dr. A. Young for the use of material in the Department of Geology, University of Cape Town; to the Keeper of the Geological Department of the British Museum for access to Salter's types.

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Classification of the Phacopidae.—In 1905 Reed suggested that the development of the family proceeded along three principal lines, typified by the genera *Dalmanites*, *Phacops*, and *Pterygometopus*, thus affording a basis for the division of the family into three subfamilies. Such a division has been generally adopted, e.g. by Raymond (1913). That conception, following on the work of Barrande (1852), Hoernes (1880), and others, was based mainly on a consideration of northern hemisphere species, and was fairly satisfactory for the data then available. But since 1905 our knowledge of the family has increased very considerably. The studies of Wedekind, Reed, the Richters, McLearn and others have considerably advanced our knowledge of boreal forms. The researches of Clarke, Kozłowski, Reed, and other workers on the Lower Devonian of South America and South Africa (the so-called austral faunas) have brought to light a wealth of Phacopid types, for which several new genera and subgenera have been proposed. Yet, in his recent excellent summary of the subgenera of the family, Reed (1927) retains in the main his earlier (1905) classification, in spite of our greatly increased knowledge of the family as a whole and of the austral species in particular. In effect, Reed has attempted to add the new austral subgenera to an old and preconceived scheme based entirely on boreal forms. In doing so, that author has disagreed with the views of Clarke (1913) and Kozłowski (1923) on the significance of the austral types. At the same time he has so greatly extended the use of the generic terms *Dalmanites* and *Phacops* as to obscure the interrelations between the various subgenera.

McLearn (1918, p. 35) has rightly pointed out that probably the most diagnostic feature of the *Phacops* line of evolution is to be found in the great reduction of the third pair of glabella lobes and the conversion of these into mere tubercles. The subgenus *Portlockia* McCoy has been revived by McLearn (1918, p. 34) for early species showing this type of specialisation, and has been accepted by Reed (1927, p. 339) as ancestral to *Phacops* (s.s.). It cannot be too strongly emphasised that *Portlockia*, *Phacops* (s.s.), *Reedops* R. and E. Richter, the austral *Dereimsia* Kozłowski, and certain small-eyed and blind derivatives form a very natural homogeneous series, characterised throughout by the peculiar specialisation of the glabella, a relatively small rounded pygidium, and a general absence of marginal spines. The genus *Phacops* should include these subgenera only. There is no justification for the inclusion of *Acaste* Goldfuss, *Calmonia* Clarke, and *Pennaia* Clarke as subgenera of *Phacops* (Reed, 1927).

No section of the family has been so misunderstood as *Acaste* Goldfuss,* genotype *Calymene downingiae* Murchison. Reed (1905, p. 225), when he founded *Phacopidella*, extended that term to include both *Acaste* and *Portlockia*, an interpretation accepted by Raymond (1913, p. 726). Williams and Breger (1916, p. 287) included in *Phacopidella* both *Acaste* and *Phacopina* Clarke. McLearn (1918) on the other hand extended *Dalmanitina* Reed to include the type of *Acaste*, in which he was followed by Barrois (1920, p. 120). The Richters (1923, p. 136; 1926, p. 200), however, recognise *Acaste* as a genus, and Reed (1927, p. 338) has satisfactorily separated *Acaste* from those groups with which it has been confused. The essentially Dalmanitid structure of the glabella of *Acaste* has been pointed out by McLearn (1918), the Richters (1923, 1926), and Kozłowski (1927); it is clear that *Acaste* is not far removed from *Dalmanitina*, the forerunner of the *Dalmanites* series, and differs from it chiefly in the absence of genal spines and the presence of a shorter, spineless pygidium.

The full significance of *Acaste*, however, can only be appreciated in the light of its time relations and of its derivatives. *Acaste* and *Dalmanitina* arise side by side in the Ordovician, but, whereas the latter gives place to *Dalmanites* (s.s.) in the Silurian, and that in turn to highly ornamented types in the Early Devonian, the evolution of the *Acaste* series remains practically at a standstill from the Ordovician until well into the Devonian. Throughout that period, however, there seems to be a sporadic development of *Acaste*-like species with small genal or caudal spines.† We are indebted to Clarke (1913) for bringing to light a significant series of forms from the Lower Devonian of Paraná, which "all bear the stamp of the same fundamental structure and all are built on the Dalmanitid model" (*ibid.*, p. 141), and which were shown to stand "in posthumous relation to the later Silurian *Acaste* of the north" (*ibid.*, p. 146). Of this series, *Pennaia* Clarke and *Calmonia* Clarke are in essentials Acastids which have acquired marginal pygidial spinules, and *Proboloides* Clarke is an Acastid with a frontal snout. *Pennaia* and *Acaste* are connected by such a species as *A. verneuli* (d'Orbigny),‡ from Bolivia, which is provided with two pairs of very minute pygidial spinules; and minute spinules are present in the European Lower Devonian species *A. atavus* (Schmidt) (1907). There seems to be no reason to doubt the survival into the Devonian of *Acaste*.

* *Acaste* Goldfuss, 1843, is not considered to be preoccupied by *Acasta* Leach, 1811 (Cirripedia), hence *Acastina* Reed, 1927, is a synonym of *Acaste*.

† E.g. *D. solitaria* Barrande and *P. apiculatus* Salter, Ordovician; *P. downingiae* var. *spinosus*, Silurian. The latter variety was designated type of *Acastella* Reed (1925a, p. 73), not *P. macrocentrus* Reed as stated later by that author (1927, p. 319).

‡ Kozłowski (1923, p. 48) has shown that *A. acutilobata* Knod (1908, p. 497) is identical with d'Orbigny's species.

though Reed (1927, p. 339) refers elsewhere the species placed in *Acaste* by the Richters, Knod, and Kozłowski.*

That *Acaste* is ancestral to the austral Lower Devonian subgenera mentioned above seems to have been clearly established. The evolution of the Dalmanitinae took place along two distinct lines. Those trends which characterise the passage from *Dalmanitina* to *Dalmanites* (s.s.) (lengthening of the glabella and partial detachment of the frontal lobe; development of the marginal border or frontal limb anterior to the glabella; lengthening of the genal spines; increasing number of segments in the pygidium) find little or no expression in the Silurian *Acaste*. And, as Clarke (1913, p. 142) has pointed out, in the Lower Devonian there are "homeomorphic developments which indicate the tendency on the part of an arrested series to follow the general line of progress or variation in the normal direct line out of which it has sprung" (cf. *Probolium* and *Proboloides*; cf. *Asteropyge* and *Calmonia*). Kozłowski (1923) rightly raised *Acaste* to generic rank, with *Pennaia*, *Calmonia*, and *Proboloides* as subgenera.

The affinities of *Typhloniscus* Salter and *Bainella* nov. are not very clear. In both groups the glabella is essentially that of the Dalmanitinae, though peculiarly modified by the weakening of the first, or first and second, pairs of lateral furrows. Kozłowski (1923) may have been right in looking upon *Typhloniscus* and "*Anchiopella* Reed" (replaced by *Bainella* nov.) as derivatives of *Acaste*, but, in view of the peculiar structure of the glabella of each group, the unique pygidium of *Typhloniscus*, and the unusual ornamentation of *Bainella*, generic rank for each of these groups seems desirable.

The following classification of the Dalmanitinae and Phacopinae is suggested. The exclusively austral Lower Devonian groups are marked with an asterisk.

Subfamily DALMANITINAE Reed, 1905.

Genus *Dalmanites* Barrande, 1852.

Subgenera: *Dalmanitina* Reed, 1905.

Dalmanites (s.s.).

Malladaia Oehlert, 1896.

Asteropyge Hawle and Corda, 1847.

Cryphina Oehlert, 1889.

Coronura Hall and Clarke, 1888.

**Metacryphaeus* Reed, 1907.

Symphoria Clarke, 1894.

Corycephalus Hall and Clarke, 1888.

* E.g. *A. schmidti* Richter (1916, p. 252), Unterkoblenzschichten; *A. perplana* Knod (1908, p. 570), Argentina; *A. lombardi* Kozłowski (1913, p. 14), Paraná.

Odontocephalus Conrad, 1840.

Probolium Oehlert, 1889.

Genus *Acaste* Goldfuss, 1843.

Subgenera : *Acaste* (s.s.).

? *Acastella* Reed, 1925.

? *Phacopina* Clarke, 1913.

**Pennaia* Clarke, 1913.

**Calmonia* Clarke, 1913.

**Proboloides* Clarke, 1913.

*Genus *Bainella*, nov.

*Genus *Typhloniscus* Salter, 1856.

Subfamily PHACOPINAE Reed, 1905.

? Genus *Phacopidella* Reed, 1905.

Subgenera : *Phacopidella* (s.s.).

? *Denckmannites* Wedekind, 1914.

Genus *Phacops* Emmrich, 1839.

Subgenera : *Portlockia* McCoy, 1846.

Phacops (s.s.).

Reedops R. and E. Richter, 1925.

**Dereimsia* Kozłowski, 1923.

**Bouleia* Kozłowski, 1923.

Trimericephalus McCoy, 1849.

Dianops R. and E. Richter, 1923.

Nephranops R. and E. Richter, 1926.

Cryphops R. and E. Richter, 1926.

The Bokkeveld Phacopidae.—Clarke (1913) was deeply impressed by the special stamp of the austral Lower Devonian faunas, and the new classification adopted here brings out very clearly the peculiarities of the assemblage of *Phacopidae* in the fauna of the Bokkeveld. Notable features are :

- (i) The absence of the *Phacopinae*, unless *Phacops* (*Bouleia* ?) *sharpei* Reed (1925B, p. 161) (founded on two pygidia) is a correct reference.
- (ii) The comparative rarity of *Dalmanites*, which is represented by several somewhat unsatisfactory species : *D. (Dalmanites) dunni* Reed (1925B, p. 133) ; *D. (Dalmanites) lunatus* Lake (1904, p. 212) ; *D. (Asteroptyge)* cf. *pentlandi* (Salter), and *D. (Asteroptyge* ?) cf. *rostratus* (Kozłowski) (Reed, 1925B, pp. 146-148). Phylogerontism is perhaps indicated by the exclusively austral subgenus *Metacryphaeus*.
- (iii) The relative abundance of *Acaste*, represented by the subgenera *Pennaia*, *Calmonia*, *Proboloides*, and possibly *Acastella*.

- (iv) The presence of two peculiar genera, *Typhloniscus* (monotypic and endemic) and *Bainella* nov. (found also in the Falklands and Paraná), possibly related to the Acastid stock.

DESCRIPTION OF SPECIES.

GENUS DALMANITES Barrande.

Subgenus DALMANITES Barrande.

Dalmanites (s.s.) appears to be represented in the fauna by the imperfectly known species *D. lunatus* Lake and *D. dunni* Reed (the latter founded on a fragmentary pygidium). It has been pointed out by Oehlert (1889, p. 758) and Reed (1905, p. 173) that *Hausmannia* Hall and Clarke is synonymous with *Dalmanites* Barrande, hence Reed was incorrect in using the former subgeneric name in his revision of the Bokkeveld fauna.

Subgenus ANCHIOPELLA Reed.

The name *Anchiopella* was introduced into the Phacopid literature by Reed (1907, pp. 168, 169) for a very characteristic element of the Bokkeveld fauna characterised by the possession of prominent axial thoracic spines. The name was given to a group of Bokkeveld species "which in many respects resembles that containing *Dalmanites anchiops* Green"; namely, *Encrinurus cristagalli* Woodward, *Phacops arbuteus* Lake, *Ph. acacia* Schwarz, and *Ph. africanus* Salter em. Lake. The group needs careful consideration, for not only are these species very imperfectly known in all their parts, but the author did not clearly signify whether *D. anchiops* Green was referable to the subgenus or not, and did not choose a genotype.

D. anchiops Green is "a very large and common boreal form of the Schoharie grit of New York, in which the genal angles are broad, produced, and sharp, the 1st and 2nd glabellar lobes so fused at their outer extremities that the separating furrows do not enter the dorsal furrows, and the frontal cephalic margin is broadened and slightly scalloped" (Clarke, 1913, p. 147). It is further characterised by the presence of a nuchal spine on the occipital segment, and the pygidium has an axis with 9-14 segments and is produced into an upturned spine.

After referring to the four Bokkeveld species, Reed goes on to state that he "would refer this whole set of species to a special subgroup of *D. anchiops* characterised (1) by fewer (typically 8) segments in the pygidium, only 5 pairs of ribs being present as a rule on the lateral lobes; (2) by the presence of median spines on the axis of thorax and pygidium; (3) by small, instead of stout and long, genal spines (in *D. anchiops*, var. *armatus*, Hall,

the genal spines are inconspicuous or obsolete); (4) by less-pronounced coalescence of first and second lateral lobes of glabella. (Nom. prop. *Anchiopella*.)" It should be noted that no genotype was selected for the subgenus. The wording is ambiguous in that it is not at all clear what is meant by "a special subgroup of *D. anchiops*," nor is it clear whether or not *D. anchiops* was meant to be included in *Anchiopella*.

At a later date, however, Reed very definitely referred to *D. anchiops* as the type of *Anchiopella*. In connection with some Silurian species, Reed (1925A, p. 75) states: "Indeed, the Lower Devonian genus *Anchiopella* possesses more of their characters, and Hall particularly mentions the usual absence of 'duplication' (=pleural furrows) on the pygidial pleurae of the type species *Dalmanites anchiops*. . . ." Since this is the first reference to a type of *Anchiopella* (as it happens by the author of that subgenus), *Anchiopella* must fall or stand on an interpretation of that species.

In the same year Reed (1925B, p. 127) enumerated the species of *Anchiopella* without referring to *D. anchiops* or to a genotype.

In his latest work on the Phacopidae Reed (1927, p. 310) states that "The type which was chosen for this special group and exemplified by *Dalmanites anchiops* Green was *Ph. cristagalli* (Woodw.). . . ." The only rational interpretation of this sentence is that Reed regarded *D. anchiops* as an example of his subgenus *Anchiopella*. Reed is incorrect in stating that *Ph. cristagalli* was chosen as the type of *Anchiopella* (in 1907), and attention has been drawn to Reed's own designation of *D. anchiops* as the type of *Anchiopella* in 1925.

Clarke (1913, pp. 147-154) retained *Anchiopella*, but the name was not used in the sense apparently intended by Reed, and at any rate cannot now be used for the South American species indicated by Clarke. Kozłowski (1923, p. 51) erroneously attributed *Anchiopella* to Clarke and placed it under *Acaste*.

Clarke (1900, p. 17), however, had previously included *D. anchiops* in his group *Synphoria*, which Reed (1927, p. 343) regards as a subgenus of *Dalmanites*, taking *D. (Synphoria) stemmatus* to be the type. The latter species is a large and abundant form from the calcareous facies of the Oriskany of Becraft Mountain, characterised by the coalescence of the first and second pairs of lateral lobes, a crenulation of the frontal border of the cephalon, and a pointed spineless pygidium. *D. anchiops* Green (Hall and Clarke, 1888, p. 59, pl. ix, figs. 1-6, 10, 12, 13; pl. x, figs. 1-14) is very similar to the foregoing, and indeed in the structure of the glabella and crenulation of the frontal border all but identical. It is, however, distinguished by the possession of a nuchal spine on the occipital segment and a slender upturned caudal spine. It is doubtful whether these characters are of sufficient importance to warrant the separation sub-

generically of these two species. Clarke believed that they were closely allied.

To sum up, the genotype of *Anchiopella* Reed is *D. anchiops* Green, which is closely allied to the genotype of *Synphoria* Clarke; *Anchiopella* must therefore be regarded as being most probably a synonym of *Synphoria*. The Bokkeveld species referred to *Anchiopella* by Reed (1925b, pp. 122-131) are dealt with below under the genus *Bainella* nov.

Subgenus EOCORYCEPHALUS, Reed.

Eocorycephalus was proposed by Reed (1925b, p. 133) for the Bokkeveld *D. (Corycephalus?) capensis* Reed, *D. stemmatus* Clarke, and other species which were said to represent an early stage in the development of the denticulated or crenulated anterior border of *Corycephalus* Hall and Clarke. In his revision of the subgenera of the Phacopidae (Reed, 1927) no mention was made of the group. No genotype was selected, but *D. stemmatus* Clarke, the best known of the species indicated, is here selected as the genotype. But *D. stemmatus* Clarke was accepted as the type of *Synphoria* Clarke by Reed (1927, p. 343). *Eocorycephalus* is therefore strictly synonymous with *Synphoria*.

As is pointed out below, *D. (Corycephalus?) capensis* Reed was founded on damaged cephalia of *D. (Metacryphaeus) caffer* (Salter) or of a variety of that species.

Subgenus METACRYPHAÆUS Reed.

The name *Metacryphaeus* was proposed by Reed (1907, pp. 167, 168) for those Bokkeveld species in which (1) there is a marked tendency for the second pair of lateral glabellar furrows to be reduced and not to enter the axial furrows, resulting in a more or less complete fusion of the first and second lateral lobes of the glabella, and in which (2) the genal spines are short or absent. The species mentioned were *Phacops caffer* Salter, *Ph. ocellus* Lake, *Ph. impressus* Lake, *Ph. callitris* Schwarz, *Ph. gylowii* Schwarz, and *Ph. ceres* Schwarz. No genotype was indicated.

Clarke (1913, p. 152) accepted the name in a group sense to include his subgenera *Calmonia*, *Pennaia*, and *Proboloides*, to the exclusion of *Ph. caffer*, and objected to the name on the grounds that it suggested a "morphologic intimacy" with *Cryphaeus* Green. Reed discarded *Metacryphaeus* in his revision of the Bokkeveld fauna, and later (1927, p. 309) suggested that the name be dropped on the grounds that he originally included in it a miscellaneous series of species. But a name once proposed cannot be discarded in that way. The writer therefore selects as genotype of *Metacryphaeus* the first species on the list originally given by Reed, viz.

Ph. caffer Salter. Moreover, that species appears to be sufficiently distinct from the type of *Asteropyge* Hawle and Corda (= *Cryphaeus* Green) to warrant the retention of the subgenus *Metacryphaeus*.

The essential features of *Asteropyge* Hawle and Corda (1847, p. 125, pl. vi, fig. 66), subgenotype *D. (Asteropyge) arachnoides* (Goldfuss) (Burmeister, 1846, p. 96, pl. iv, fig. 7),* are well known. In addition to the five pairs of marginal pygidial spines, the subgenus is characterised by the following features. The cephalon is subtriangular, more or less pointed anteriorly. The glabella is elongated, with well-defined segmentation, partly detached frontal lobe, free lateral lobes, and the eyes are set well back. There is a well-defined, broad, frontal limb or border, and the genal angles are produced posteriorly into long, stout genal spines. In fact, the cephalic structure of *Asteropyge* is all but identical with that of *Dalmanites* (s.s.). It should be remarked here that Reed (1925b, pp. 321, 348) is probably right in suggesting that *Metacanthus* Hawle and Corda and *Comura* R. and E. Richter should not be separated from *Asteropyge*.

It was long ago pointed out by Reed (1905, p. 173) that *Cryphaeus* Green, 1837, is preoccupied by *Cryphaeus* Klug, 1833 (Coleoptera), and the former name has accordingly been discarded by many authors, though Reed (1927, p. 344) has recently revived it, against the rules of nomenclature. The type of *Cryphaeus* Green, *C. boothi* Green (Hall and Clarke, 1888, pp. 42-48, pls. xvi, xvii) resembles *Asteropyge* very closely in structure; *Cryphaeus* Green and *Asteropyge* have been regarded as synonymous by Reed (1905, p. 173; 1927, p. 344), the Richters (1926, p. 211), and other authors.

D. caffer (Salter) (references are given below), on the other hand, differs from *C. boothi* Green and from the type of *Asteropyge* in several important points. The cephalon is markedly shortened. The glabella is short and broad, with a large transverse, inflated frontal lobe. The lateral lobes coalesce distally, so that the second and third lateral furrows are represented by transversely oval pits. The frontal limb or border is poorly developed, narrow, but produced anteriorly into a short rostrum. The genal angles are not produced posteriorly, but are subangular or bluntly pointed.

The cephalon of *Metacryphaeus* and *Asteropyge* are very readily distinguished by the characters mentioned above. The short, compressed cephalon and glabella of the former, with fused lateral lobes, very narrow anterior border, and blunt genal angles, is peculiar. It is generally recognised that the passage from *Dalmanitina* to *Dalmanites* (s.s.) and its ornamented derivatives is characterised by the lengthening of the glabella and the wide separation of the lateral lobes, the increasing length and

* According to the Richters (1926, p. 211) the genotype is synonymous with the earlier *D. punctatus* (Steininger) (1834, p. 356, pl. xii, figs. 7, 7a, 7b).

strength of the genal spines, and the development of the frontal border. These trends find full expression in *Asteropyge* [*Cryphaeus*], and it is therefore rather remarkable that Lake (1904, p. 210) and Reed (1925b, p. 139) have retained the term *Cryphaeus* for the type of *Metacryphaeus*, and to find too that Clarke has described an allied species from Brazil under the title *C. australis* (1913, p. 108, pl. iii, figs. 7-14; pl. iv, figs. 1-5). While it must be admitted that *Metacryphaeus* is closely allied to *Asteropyge*, it appears to the writer that the differences in cephalic structure are sufficiently remarkable to justify the acceptance of *Metacryphaeus* as a distinct subgenus of *Dalmanites*. *Metacryphaeus* appears, moreover, to be better founded than several subgenera based mainly on ornamental characters, e.g. *Comura* R. and E. Richter. In *Metacryphaeus* the prevalent cephalic type of the later *Dalmanites* (s.l.) is not in evidence, and the compressed state of the cephalon possibly indicates a phylogerontic condition.

Dalmanites (*Metacryphaeus* ?) *ceres* (Schwarz).

Plate IX, figs. 1, 2.

1906. *Phacops* (*Cryphaeus*) *ceres* Schwarz: Rec. Alb. Mus., vol. i, p. 394, pl. x, figs. 1, 1a (67 Alb. Mus.).

1925. *Dalmanites* (*Cryphaeus* ?) *ceres* (Schwarz). Reed: Ann. S. Afr. Mus., vol. xxii, p. 148.

Reed has pointed out that the type figure is poor, hence the type and paratype of the species are figured here. Reed associates with *D. ceres* a cephalon figured by Lake (1904, p. 203, pl. xxiv, fig. 3), but this the writer considers to be a *Bainella* (q.v.).

Dalmanites (*Metacryphaeus*) *caffer* (Salter).

Plate IX, figs. 3, 4.

1856. *Phacops* (*Cryphaeus*) *caffer* Salter (pars): Trans. Geol. Soc. Lond., ser. 2, vol. vii, p. 219, pl. xxv, figs. 11, 12, 12a (11290 Br. Mus.), non figs. 10, 13.

1856. *Phacops africanus* Salter (pars): Trans. Geol. Soc. Lond., ser. 2, vol. vii, p. 218, pl. xxv, fig. 4 (11286 Br. Mus.), non *cet*.

1904. *Phacops* (*Cryphaeus*) *caffer* Salter. Lake: Ann. S. Afr. Mus., vol. iv, p. 210, pl. xxv, figs. 3 (18 Cape Geol. Surv. Coll., now 7185 S.A. Mus.), 4 (34 C.G.S. Coll., now 7184 S.A. Mus.).

1925. *Dalmanites* (*Cryphaeus*) *caffer* (Salter). Reed: Ann. S. Afr. Mus., vol. xxii, p. 139, pl. ix, figs. 10 (175 Cape Univ. Coll., now 7790 S.A. Mus.), 11 (179 Cape Univ. Coll., now 7789 S.A. Mus.); pl. xi, fig. 4 (E483 Stell. Univ. Coll.).

- ? 1925. *Dalmanites* (*Corycephalus*?) *capensis* Reed: Ann. S. Afr. Mus., vol. xxii, p. 131, pl. viii, figs. 5 (H76 Stell. Univ. Coll.), 6 (H172 Stell. Univ. Coll.).

The Types of D. capensis Reed.—Reed founded the species *D. (Corycephalus?) capensis* on three cephalons from localities near the Hex River Pass. It was stated that "The head-shields of *D. capensis* and *D. caffer* are difficult to distinguish when the anterior margin and ornamentation are not preserved, as the glabella and general characters seem to be identical." On account of a supposed crenulation of the anterior margin of the cephalon the species was referred to *Corycephalus*?, and the new name *Eocorycephalus* was suggested for it and for *D. stemmatus* Clarke "if a distinctive subgeneric name is required."

The writer has examined the three co-types of the species, and concludes that *D. capensis* was founded on damaged cephalons of *D. caffer* or of some closely allied variety. In each case the cephalon has been crushed dorso-ventrally, resulting in a flattening and fracturing of the anterior margin; as a consequence Reed thought he was able to discern an original wavy or crenulated anterior margin.

The first figured co-type (Reed, 1925B, pl. viii, fig. 5, H76 Stell. Univ. Coll.) is a somewhat weathered cephalon with portions of three thoracic segments attached. The whole specimen is rather crushed and has the appearance of having been flattened dorso-ventrally. The accompanying figure is misleading in that there is little indication of the weathered, somewhat flaky, state of the surface of the specimen. In general features, and in particular in the structure of the glabella and the nature and position of the furrows, there is nothing to distinguish the cephalon from that of *D. (Metacryphaeus) caffer*. The nature of the ornamentation is extremely obscure, though there are traces of tubercles on the left fixed cheek. Examination of the anterior margin made it perfectly clear that the marginal projections (which, as Reed states, are indistinctly seen) are not original features. The upper and under sides of the anterior part of the cephalon have evidently been pressed together, and the process of flattening has very naturally resulted in the development of a marginal line of fracture. The margin is consequently somewhat roughened or jagged, and the very abrupt bending back of the doublure is quite evident.

The second figured co-type of *D. capensis* Reed (1925B, pl. viii, fig. 6, H172 Stell. Univ. Coll.), preserved in a dark micaceous mudstone, consists of the greater part of a cephalon. The surface is not well preserved and the nature of the ornamentation is obscure; dark, ferruginous patches on the glabella bear small granulations, but these may not represent original ornamentation. The anterior margin is roughened or jagged (it can hardly be called crenulated) as in the first co-type. Inspection shows that the

cephalon has been flattened dorso-ventrally as in the other specimen, with like results at the anterior margin.

The third co-type (216 Cape Univ. Coll.) was not figured, although in some respects it is the best preserved of the three specimens. It was collected by A. R. E. Walker and F. C. Partridge at a roadside cutting near Buffelskraal on the Touws River Road, along with several cephala of *D. caffer* (142, 169, 175, 179 Cape Univ. Coll.). Reed states that "it shows clearly the marginal denticulations of the border in front of the frontal lobe, and is not much crushed." Close inspection, however, shows quite clearly that the cephalon has been flattened dorso-ventrally as in the figured co-types. Moreover, the right side has been sharply bent down beyond a line which passes just beneath the right eye. The right eye and the fixed and free cheeks beyond it have been considerably damaged. Further, the line of fracture is continued round the front of the frontal lobe and demonstrates very clearly how the so-called denticulated border was produced. An almost precisely similar cephalon collected by A. R. E. Walker at Keurbosch in the Hex River area (269 Cape Univ. Coll.) was identified by Reed with *D. caffer*; in this case the left free cheek has been crushed and bent down, the line of fracture being continued round the front of the cephalon. Apart from the large, low, closely placed, rounded tubercles on the cheeks between the eyes and the genal angles, the third co-type does not appear to be distinguishable from *D. caffer*.

D. capensis is certainly a *Metacryphaeus*. Neither of the figured co-types appears to possess features by which the species can be separated from *D. caffer*, apart from a mere suspicion of large tubercles preserved on the left fixed cheek of the first figured co-type. It is therefore concluded that *D. capensis* is either a variety of, or actually identical with, *D. caffer*. The third co-type, not figured by Reed, is distinguishable only by the presence of large cheek tubercles; it appears to be a variety of *D. caffer*, and may or may not be identical with the figured co-types of *D. capensis*.

GENUS ACASTE Goldfuss.

Subgenus PENNAIA Clarke.

Acaste (Pennaia) impressus Lake.

Plate IX, figs. 5-13.

1904. *Phacops impressus* Lake: Ann. S. Afr. Mus., vol. iv, p. 209, pl. xxv, figs. 1a, 1b (43 Cape Geol. Surv. Coll., now 7187 S.A. Mus.), 2 (50 C.G.S. Coll., now 9605 S.A. Mus.).

1906. *Phacops (Cryphaeus) gydowi* Schwarz : Rec. Alb. Mus., vol. i, p. 396, pl. x, figs. 3, 3a, 3b (28 Alb. Mus.), 3c (26 Alb. Mus.).
1925. *Phacops (Calmonia) impressus* Lake. Reed : Ann. S. Afr. Mus., vol. xxii, p. 150.
1925. *Phacops (Calmonia) impressus* Lake var. *vicina* Reed : Ann. S. Afr. Mus., vol. xxii, p. 151, pl. xi, fig. 8 (418 Kimb. Mus.).
1925. *Phacops (Pennaia) gydowi* Schwarz. Reed : Ann. S. Afr. Mus., vol. xxii, p. 157, pl. ix, figs. 7, 7a (1167 S.A. Mus.); pl. xi, fig. 2 (Bloemf. Mus.).

The species *Ph. impressus* Lake was created for a number of specimens from Gamka Poort, most of them almost certainly from the Lowest or Basal Shales. Two of these were figured, namely, a complete but crushed individual (Lake's figs. 1a, 1b) and a pygidium (Lake's fig. 2).

The commonest trilobite in the Basal Shales at Gamka Poort is represented in the new material by portions of at least twelve individuals, including some exceptionally well-preserved cephalons. The writer has carefully compared these with the types of *Ph. impressus* and with the type of Reed's variety *vicina*, all from the same locality and almost certainly from the same horizon, and does not hesitate to state that they belong to the same species. Moreover, comparison of these in turn with Reed's figured specimen of *Ph. gydowi* Schwarz from the neighbouring locality of Boschluis Kloof, and with the type of *Ph. gydowi* from Gydow Pass, shows that *Ph. gydowi* Schwarz is identical with *Ph. impressus* Lake.

Specific Diagnosis.—Cephalon transversely semicircular to subtriangular, wider than long, very gently convex, obtusely angulated in front. Glabella large, longer than wide, widening slightly anteriorly, not much inflated. Frontal lobe not much inflated, obtusely angulated in front, wider than long. First pair of lateral furrows long, well marked but not deep, obliquely placed, almost straight, slightly bent posteriorly at the inner ends. Second pair of lateral furrows shorter, well marked but not deep, horizontally placed, not reaching the axial furrows. Third pair of lateral furrows deeper than the other two, curving forward very slightly on entering the axial furrows. First and second pairs of lateral lobes broad, flattened above, coalescing distally. Third (basal) pair of lateral lobes broad, flattened above, widening slightly distally. Furrows reaching inwards to rather more than $\frac{1}{4}$ of the width of the glabella. Axial furrows nearly straight, very slightly concave to the cheeks, diverging slightly anteriorly, well marked, narrow. Occipital furrow well marked; meso-occipital furrow wide and deep over the axis, narrower but very deep behind the basal lobes; pleuro-occipital furrows very slightly concave forward, well marked, meeting the weaker marginal furrow at a large angle. Meso-occipital segment strong, flattened above; pleuro-occipital segment

broadening towards the genal angles. Cheeks triangular, with well-defined lateral border. Genal angles produced very slightly backwards, well rounded or very bluntly pointed. Facial sutures proceeding almost horizontally outwards from the posterior ends of the eyes, slightly curved anteriorly. Eyes large, moderately elevated; lens-bearing surfaces large, curved, with somewhat closely packed lenses arranged in 25-32 vertical rows with 9-14 lenses in the central rows; eyes close to axial furrows at anterior end, reaching from first lateral furrows to basal furrows.

Thorax of eleven segments. Axis semi-cylindrical, about as wide as the pleural portions. Axial rings slightly swollen at their lateral extremities. Pleural lobes bent down at a rounded fulcrum situated at about two-fifths of their length; beyond the fulcrum each lobe is curved backwards and then forwards to the tip. Tips of the pleural lobes truncate, the posterior corner furnished with a small point. Pleural furrows strong, nearly straight, diagonal, with a large bevelled anterior facet for enrolment.

Pygidium semicircular to subtriangular; axis slowly tapering, almost reaching the posterior margin and composed of 8-10 rings, the posterior rings very faintly marked. Axial furrows well marked. Lateral parts of pygidium very gently convex, with 5-6 flattened pleurae, each separated by a deep, well-defined groove. Each pleura with a faint median furrow, sometimes only discernible in the outer half, where it lies rather close to the posterior side of the pleura. Interpleural grooves not extending to the margin. Pygidium provided with a smooth, undefined marginal band, without an inner marginal furrow. Margin provided with 3 pairs of very short, broad, triangular, sharp spinose projections, corresponding to the first three pleurae; behind these marginal spinules the margin is apparently entire and simply rounded in most individuals.

Surface of cephalon and thorax in well-preserved specimens covered with small, round, low tubercles, rather widely spaced and with minute granulations between.

(Typical dimensions for "*Ph. gydowi*" have been given by Reed, 1925b, p. 158.)

Remarks.—The above, fairly complete description of the species is based on the types of *Ph. impressus*, of the var. *vicina*, and of *Ph. gydowi*, together with topotypic specimens of *Ph. impressus*.

The more complete type of *Ph. impressus* (7187 S.A. Mus.) is an almost complete, partly enrolled, but distorted and crushed individual. Nevertheless, the essential features of the species are indicated with sufficient clarity to identify with it the numerous topotypes which have since been collected. The cephalon, although crushed from back to front and slightly distorted, agrees in every respect with those of the topotypes. In particular, the nature and disposition of the furrows and lobes of the glabella are per-

fectly evident, including the slight upward curvature of the basal furrows on entering the axial furrows. The left eye, though bent abruptly across the centre of the lens-bearing surface, is well preserved; the lenses are exactly like those of the topotypes in size, disposition, and number. Only the first seven thoracic segments are preserved, including the terminations of a few of the right pleural lobes; in width of axis, nature and disposition of the axial furrows, fulcræ, pleuræ and pleural terminations, the thorax of the type cannot be distinguished from those of the new topotypes. The pygidium is almost complete, though somewhat flattened by pressure, and, like the thorax, can be almost exactly matched among the new material; the margin is not quite complete, but three marginal spinules at least are clearly indicated, possibly a fourth. Lake's second figured specimen, a pygidium (9605 S.A. Mus.), has the margin less clearly preserved, but is identical with the pygidium of the other type in general structure and in certain details, e.g. the depth of the interpleural grooves and the strength of position of the faint furrows on the pleuræ. In short, both of Lake's figured specimens fit exactly into the extended diagnosis given above.

The variety *vicina* was founded by Reed (1925B, p. 151) for a single, nearly complete specimen with considerably damaged cephalon (418 Kimb. Mus.). Reed states of this specimen that "apart from the curious curvature of the basal furrows, causing the conjoint first and second lateral lobes of the glabella to have a rounded external outline and the larger eyes, there seem to be no distinctive characters by which we can separate it from *Ph. impressus*." The writer has carefully examined the types and indeed cannot find any points of distinction between them; both types, it should be noted, are from Gamka Poort, and very probably from the same horizon, the Basal Shales. Reed states that the variety *vicina* has larger eyes than *Ph. impressus*; but the whole of the left side of the cephalon is missing and the right side is very much crushed and broken; the right eye is represented by a large fracture-scar, and the posterior end of the lens-bearing surface (on which a few lenses are discernible) has been so distorted that the few remaining lenses are actually facing the basal glabella furrow; close examination fails to bring out any real distinction between the eye of the variety and that of *Ph. impressus*. Moreover, Reed states that the "curious curvature of the basal furrows" is peculiar to the variety *vicina*; but the type of *Ph. impressus* shows exactly the same condition, namely, a slight forward curvature of the basal furrows on entering the axial furrows, "causing the conjoint first and second lateral lobes of the glabella to have a rounded external outline." And the same feature is repeated with varying degrees of clarity in the rest of the material here included in *Ph. impressus*. Further, it was stated that the first lateral furrows of the variety *vicina* "are represented by shallow, isolated pits, very faint or obsolete"; but

the type (as the published figure quite clearly shows) is not in a condition to give positive evidence as to the nature of the first lateral furrows, and there is no reason to conclude that they were in any way different from those of *Ph. impressus*. And lastly, the margin of the pygidium is too damaged to indicate the exact number of marginal spinules, only the first (?) and second being indicated. In short, the variety *vicina* is not different in any way from *Ph. impressus*. The proposal of the varietal name seems to have been quite unnecessary.

Phacops gydowi Schwarz (1906, p. 396) was proposed for a cephalon and "two rather indistinct specimens of the whole animal" from the Gydow Pass, north of Ceres. The cephalon (28 Alb. Mus.) was designated "type for head" by Schwarz, and is here selected as type of the species. The second specimen partly figured by Schwarz (26 Alb. Mus.) is almost worthless; but the left lateral furrows and general form suggest the same species. The writer has compared the type cephalon with the almost complete example of *Ph. gydowi* figured by Reed, and both of these with the type and topotypes of *Ph. impressus*, and can find no points of difference. It would be unnecessary to enumerate the points of identity in each case. It suffices to state that the specific diagnosis given above applies even in minute detail to the numerous topotypes of *Ph. impressus*, and these cannot be distinguished in any way from the type cephalon of *Ph. gydowi* and from Reed's complete individual of the latter species.

There are one or two specimens from the Basal Shales at Gamka Poort which deserve special notice. One nodule (8966 S.A. Mus.) contains an exceptionally well-preserved cephalon (with the first thoracic segment attached), the mould of part of a similar cephalon, and a well-preserved pygidium. The complete cephalon is rather smaller than the type of *Ph. gydowi* (18 mm. wide, 11 mm. long) and agrees with *Ph. impressus* in all the details of glabellar and eye structure; attention is drawn to the anterior margin, which is only very obscurely angulated in front, whereas in other cephalons of *Ph. impressus* the anterior angulation of the cephalon is quite evident. The feature does not appear to be of much importance; in all other respects the cephalon is indistinguishable from that of *Ph. impressus*. The left margin of the accompanying pygidium is exceptionally well preserved and shows quite clearly the presence of a minute, blunt, fourth marginal spinule; the marginal spinules are most prominent anteriorly and become progressively smaller towards the posterior.

There is one small nodule from the Basal Shales at Gamka Poort (8969 S.A. Mus.) crowded with very well-preserved trilobite fragments; these include an almost complete adult individual and part of an adult cephalon of *Ph. impressus*, three very small but well-preserved cephalons apparently belonging to the same species, and a juvenile *Homalonotus* cephalon. One

of the very small cephalon (8 mm. wide, 4.5 mm. long) is of special interest, since it possesses very clearly indeed a short spinule on the corner of the subangular left genal angle. In all other features it appears to be a juvenile example of *Ph. impressus*; if so, then it would seem that the presence or absence of a small genal or supra-genal spinule in the Phacopidae is not a feature of much importance from the classificatory point of view. (A distinction must be made between genal or supra-genal spinules and genal spines due to posterior production of the genal angle.)

Affinities.—The differences between Clarke's subgenera *Calmonia* and *Pennaia* (1913, pp. 119–135) are by no means clear and certainly not very great. Clarke appears to have relied on pygidial ornamentation when separating the two groups. *Pennaia pauliana* Clarke (type of *Pennaia* by monotypy) is characterised by the presence of three pairs of rather small marginal spinules corresponding to the first three pairs of pygidial pleurae; while *Calmonia signifer* Clarke (designated type of *Calmonia* by Reed, 1927, p. 314) bears six pairs of larger marginal spinules and an elongated caudal spine. These types appear to be connected by such forms as *C. signifer* var. *micrischia* Clarke and *C. subseciva* Clarke. In most specimens of *Ph. impressus* only three pairs of small spinules are indicated, but in one topotype a fourth minute pair is unmistakably present. *Ph. impressus* should be placed in *Pennaia* rather than in *Calmonia*. Reed (1925B, p. 158) has pointed out the close relationship of *Ph. gydowi* to *Pe. pauliana*; *Ph. impressus*, with which *Ph. gydowi* is identical, has a slightly longer glabella and larger eyes than *Pe. pauliana*, and the pygidium appears to be larger and more extended posteriorly. A noteworthy and apparently constant difference lies in the size of the marginal spinules; in *Pe. pauliana* these are comparatively large and elongated, the third pair projecting below the posterior point of the pygidium; in *Ph. impressus* the spinules are invariably smaller and shorter, and the posterior point of the pygidium projects far below the third pair.

Calmonia subseciva Clarke (1913, p. 126, pl. vii, figs. 2–10) appears to be closely allied, but the eyes are smaller and the marginal spinules more minute.

Pennaia africana Shand (1914) is almost certainly a *Calmonia*. Reed (1925B, p. 158) has drawn attention to the *Calmonia*-like aspect of the cephalon; the pygidium of the holotype is incomplete, hence the exact number of spinules is uncertain; the first three pairs of spinules are present and are much larger than those of either *Pe. pauliana* or *Ph. impressus* and resemble very closely those of *C. signifer*.

Subgenus CALMONIA Clarke.

Acaste (Calmonia) callitris (Schwarz).

Plate IX, fig. 19.

1906. *Phacops (Cryphaeus) callitris* Schwarz : Rec. Alb. Mus., vol. i, p. 393, pl. x, figs. 2, 2a, 2b (29 Alb. Mus.).

1925. *Phacops (Calmonia) callitris* Schwarz. Reed : Ann. S. Afr. Mus., vol. xxii, p. 149.

The drawing given by Schwarz of the type cephalon of this species is incorrect in certain details, as Reed has pointed out. This opportunity is taken of publishing a photograph of the type. Reed has pointed out the resemblance to the type of *Calmonia*, which is here regarded as a subgenus of *Acaste*.

Acaste (Calmonia) africana (Shand).

1914. *Pennaia africana* Shand. Trans. Geol. Soc. S. Afr., vol. xvii, p. 24, pl. vi, figs. 1-14 (E 417 Stell. Univ. Mus.).

1925. *Phacops (Pennaia) africanoides* nom. prop. (= *africana* Shand, non Salter). Reed : Ann. S. Afr. Mus., vol. xxii, p. 158.

Reed remarks of this species that the cephalon might well be referred to *Calmonia*, but nevertheless retains the species in *Pennaia*. The cephalon bears a certain resemblance to that of *A. (Calmonia) callitris*, e.g. in the shape of the genal angle. The posterior part of the pygidium is missing and only the first two pairs of marginal spinules are clearly present. Since the subgeneric distinction between *Calmonia* and *Pennaia* rests largely on the number of pygidial spinules, it cannot at present be definitely ascertained to which subgenus the species should be referred. But since the spinules are much larger than those of *A. (Pennaia) pauliana* (Clarke) (1913, p. 133) and *A. (Pennaia) impressus* (Lake), and since the cephalon is distinctly *Calmonia*-like, reference to *Calmonia* seems to be most probable.

GENUS BAINELLA Nov.

The very distinctive assemblage of Bokkeveld Dalmanitinae characterised by the possession of stout axial thoracic spines cannot now be referred to *Anchiopella* Reed. For them the new genus *Bainella* is proposed, in honour of Andrew Geddes Bain, the great pioneer geologist of S. Africa. The new species *Bainella bokkeveldensis* (erected for the bulk of the material referred by Reed to Salter's *Ph. africanus*) is now the most completely known species belonging to the group, and is accordingly selected as genotype.

The genus is characterised by the following features.

Cephalon stout, broader than long, with rounded or shortly pointed genal angles and narrow anterior border. Glabella subpentagonal, compact, about as long as broad. Frontal lobe not strongly separated from the posterior portion of the glabella. Glabellar furrows unequally developed; first and second pairs weak and third pair more deeply impressed. Occipital segment bearing a well-developed nuchal spine.

Thorax tapering slightly, with a broad axis, each segment bearing a well-developed median spine.

Pygidium convex, inflated, subtriangular, bluntly pointed or spined posteriorly, with entire margin. Axis prominent, spineless, of 8-10 segments.

Bainella is apparently represented in the Bokkeveld fauna by several species, though it is to be regretted that some of these are very imperfectly known. In addition to the genotype, the only species tolerably well known in all its parts is *D. bairdi* Reed (1925B, p. 129, pl. ix, figs. 1-3), which agrees with the genotype in essential features and was referred to the *Anchiopella* group by Reed.

The species *Ph. africanus* Salter and *Ph. acacia* Schwarz are dealt with below, and a remarkable cephalon from Gamka Poort is described below as *Bainella gamkaensis* sp. nov.

Besides the foregoing species, in which the surface is covered with very fine tubercles, several specimens have been collected and described from time to time which have been associated with the *Anchiopella* group on account of the possession of thoracic or nuchal spines, but which are further characterised by being covered with coarse tubercles. Unfortunately in no case has a complete individual come to light. In spite of recent collecting, no specimen has been found which can with certainty be identified with the remarkable thorax-plus-pygidium described as *Encrinurus cristagalli* by Woodward (1873, p. 31, pl. ii, figs. 6, 7). The convexity of the pygidium and the stout axial thoracic spines certainly recalls *Bainella* and strongly suggests the inclusion of the species in that subgenus; the coarse tuberculation and stout upturned caudal spine are, however, striking points of difference. Several cephalae are now known which resemble that of *Bainella* in some of their principal features, but which are covered with moderately coarse tubercles. *D. arbutus* (Lake) (1904, p. 203, pl. xxiv, fig. 2) consists of a distorted glabella and meso-occipital segment bearing a short, stout median spine; coarse tuberculation of the glabella has suggested to both Lake and Reed (1925B, p. 128) that it may possibly be the cephalon of *D. cristagalli*; at the same time the glabella is compact and appears to have been subpentagonal, and though the furrows are almost equal in strength, reference to *Bainella* is probable. Other cephalae of similar type but finer tuberculation are one figured by Lake (1904, pl. xxiv, fig. 3) and one described below as *Bainella* sp.

The subgenus is undoubtedly represented in the equivalent fauna of the Falklands, whence Clarke (1913, p. 116, pl. v, figs. 5-9) has figured isolated cephalo and a thorax-plus-pygidium under the term *D. acacia* (Schwarz). Reed (1925b, p. 122) has accepted the identification of the thorax-plus-pygidium with *D. acacia* (Schwarz) and with *D. africanus* (Salter), but while admitting the occurrence of *Bainella* in the Falklands, it may be doubted whether the evidence is sufficient to prove the identity of the species. The cephalo do not precisely agree with those here included under *Bainella bokkeveldensis*, as Reed has remarked.

The Bolivian *Anchiopella haugi* Kozłowski (1923, p. 51, pl. ii, figs. 11-14) is strongly recalled by the cephalon described below as *Bainella* sp.

Bainella ? *africanus* (Salter).

1856. *Phacops* (*Cryphaeus*) *africanus* Salter (*pars*); Trans. Geol. Soc. Lond., ser. 2, vol. vii, p. 218, pl. xxv, fig. 1 (*non cet.*).

In spite of the uncertainty as to what Salter meant by the term *Phacops africanus*, the name continues to haunt Bokkeveld literature. It seems to the writer that an inquiry into the validity of the species is necessary.

The original description given by Salter was based on several incomplete specimens which have been shown by Lake and Reed to belong to four or five different species. Lake (1904, p. 206) accordingly selected Salter's first figure (pl. xxv, fig. 1) as the type figure of the species, but was unable to recognise in the collections the specimen from which that figure was taken. Reed (1925b, p. 123) stated that "it may be regarded as fairly certain that the poor specimen in the British Museum, numbered 11295, from Leo Hoek, was the one from which Salter's partially restored figure was drawn, and it may have been that the specimen was subsequently somewhat damaged," but also admitted that the specimen was now in such a condition that "we could hardly give a satisfactory definition of the species." Both Lake and Reed described specimens of *Ph. africanus*, using Salter's first figure as their basis for the interpretation of the species.

The writer has been able to examine the British Museum specimen referred to, and is emphatically of the opinion that it is not the original of Salter's figure ("a specimen of the largest size, with the crust removed," Salter, 1856, p. 229) and therefore cannot be accepted as the holotype of the species. Moreover, the specimen is incomplete and too badly damaged to be of service. It is clear that *Ph. africanus* can only be interpreted from the figure selected by Lake as the type figure, since (a) the original description is composite and, strictly speaking, meaningless, and (b) the holotype cannot now be found.

Under the circumstances what use can be made of the name *Ph. africanus*?

Is it possible to say with certainty that a given specimen belongs to the same species as the lost original of the type figure? Do the specimens of "*Ph. africanus*" figured by Lake and Reed belong to the same species as the lost holotype? In short, is Salter's first figure sufficient to define *Ph. africanus* and to render it intelligible?

Salter's first figure depicts the greater part of the cephalon and thorax. Almost the whole of the glabella is present, as well as the greater part of the left side of the cephalon. Ten segments of the thorax, together with the first six left pleurae ending in sharp posteriorly directed points, are included in the figure. Noteworthy is the absence of data relating to the presence or absence of axial thoracic spines (except that the meso-occipital segments are all broken across their summits), also the lack of evidence as to the nature of the genal angles (though Salter has dotted in a short left genal spine).

The best specimen of "*Ph. africanus*" that has so far been figured is a complete, partly enrolled individual (I 4047 Br. Mus.) figured by Reed (1925B, p. 125, pl. viii, figs. 1, 1a-c). The writer cannot agree with Reed that it belongs to the same species as the type of *Ph. africanus* (assuming that Salter's figure was correctly drawn). The latter is incomplete in that there is no positive indication of nuchal or axial thoracic spines, which are quite evident in Reed's specimen. Further, there are positive points of difference. Reed's specimen has a markedly subpentagonal glabella, with almost straight lateral margins diverging at a relatively small angle, the antero-lateral angles being moderately rounded. On the other hand, in Salter's figure the anterior portion of the glabella is considerably wider than the lobed posterior portion, the lateral margins are concave, and the antero-lateral angles are well rounded. Moreover, in Salter's figure the lobation of the glabella is rather more marked, the two anterior pairs of furrows being much more distinct. Assuming that Salter's figure was correctly drawn, these points of difference appear to indicate a specific distinction between the type of *Ph. africanus* and Reed's specimen.

Lake's individuals (27, 67, 222 Cape Geol. Surv. Coll.) are not so well preserved, but the data presented certainly support their identification (Reed, 1925B, p. 122) with Reed's specimen and their separation from *Ph. africanus*.

There seems to be but one course open under the circumstances. Lake has definitely selected Salter's first figure for an interpretation of *Ph. africanus*. The type has disappeared and the original description of the species (having been based on several unrelated individuals) is misleading. Subsequent figures of "*Ph. africanus*" fail to agree with the type figure. The name should be retained for that figure only, and no longer used for the specimens which have from time to time been referred to it. It is of course possible,

perhaps even probable, that Salter's first figure is an incorrect figure of the lost type, which may have belonged to the same species as the individuals considered above; but the writer believes that no good purpose can be served by assuming that to be the case.

Bainella acacia (Schwarz).

Plate X, fig. 5.

1906. *Phacops acacia* Schwarz: Rec. Alb. Mus., vol. i, p. 398, pl. x, figs. 4, 4a (2124 Alb. Mus.).

Non 1913. *Dalmanites (Anchiopella) acacia* (Schwarz). Clarke: Foss. Devon. Paraná, p. 116, pl. v, figs. 5-9.

Schwarz created this species for fragmentary Phacopid remains (contained in two nodules) whose thoracic axes bear strong median spines, while admitting that they might ultimately prove to be specimens of *Ph. africanus* Salter. He designated as type the external moulds of part of a thorax and a fragment of a cephalon contained in a nodule from an unknown locality (2124 Alb. Mus.). Reed (1925B, p. 122), who re-examined the type, accepted the reference to Salter's species. But it has been shown above that *Ph. africanus* cannot now be recognised, and hence it becomes necessary to ascertain whether *Ph. acacia* Schwarz should be revived for the specimens of "*Ph. africanus*" figured by Lake and Reed.

It should be pointed out at the outset that the figures given by Schwarz are misleading, in that his fig. 4 was based only partly on the type fragment of the cephalon, and both figures fail to give a true picture of the original specimens. The description accompanying these figures was based on the specimens contained in both nodules. Moreover, Reed (1925B, p. 126), when purporting to be describing the type cephalon, actually gave details not seen in the type cephalic fragment, but in the two fragmentary cephalic impressions contained in the second nodule used by Schwarz, thus giving a false impression of the value of the type fragment.

The holotype of *Ph. acacia* consists of two fragments, external moulds, presumably parts of one individual. The thorax is slightly enrolled, and only part of the axis and some of the right pleurae are present. Seven segments of the axis are clearly present, each one bearing the mould of a strong median spine, and there is also the mould of part of an eighth spine. Seven right pleurae are attached, but the distal ends of these are not clear. In addition, a very small fragment of the anterior part of the pygidium is present. The mould clearly indicates the occurrence of minute scattered tubercles on all parts of the thorax. The impression of the cephalic fragment is much less satisfactory; it consists of the meso-occipital segment with nuchal spine, and a small portion of the right side of the cephalon.

Reed states that "the genal spines, which are the important distinction, are not clearly distinguishable." That is incorrect. In the holotype the mould of the right genal spine is just as clearly indicated as are those of the nuchal and axial thoracic spines. But the drawing given by Schwarz is untrue; a fresh gelatine cast showed quite clearly that the right genal angle is well rounded, not posteriorly produced, and bears a stout spine, approximately equal to the nuchal spine in dimensions, directed somewhat postero-laterally (text-fig. 1). No details of the glabella are present in the holotype; those mentioned by Reed were taken from the second nodule, not the type nodule (2124 Alb. Mus.) as stated. The surface of the type cephalic fragment is covered with minute scattered tubercles.



TEXT-FIG. 1.

The second nodule used by Schwarz for his description contains moulds of part of a thorax and two cephalons and part of the internal cast of another individual. All of these are poorly preserved and in a very fragmentary condition, though the details of glabella structure are partly in evidence and recall the glabella of *B. bokkeveldensis* sp. nov.

The holotype of *Ph. acacia* undoubtedly resembles *B. bokkeveldensis* sp. nov. very closely, and there do not appear to be any characters by means of which the thorax of the former species can be separated from that of the latter. The pygidium of *Ph. acacia* is unknown, as is also most of the cephalon. The genal angles of *B. bokkeveldensis* have not yet been properly observed, and Reed believed that they were not spinose; on the other hand, the genal angles of *Ph. acacia* are very definitely spinose. Thus there do not appear to be any characters which definitely separate the two species. But considering the very incomplete state of the holotype of *Ph. acacia*, it seems that the identity of the species cannot be accepted as being more than a probability. The writer has accordingly, though not without considerable hesitation, decided to restrict the name *Ph. acacia* to its holotype, to regard the species as not specifically recognisable, and to erect a new species *B. bokkeveldensis* for the remainder of the material.

Bainella bokkeveldensis sp. nov.

Plate X, figs. 1-4.

1904. *Phacops cristagalli* (Woodward). Lake: Ann. S. Afr. Mus., vol. iv, p. 205, pl. xxiv, fig. 5 (27 C.G.S. Coll., now S.A. Mus.).
 1904. *Phacops africanus* Salter. Lake: Ann. S. Afr. Mus., vol. iv, p. 205, pl. xxiv, fig. 6 (67 C.G.S. Coll., now 7183 S.A. Mus.), fig. 7 (27 C.G.S.

Coll., now 7179 S.A. Mus.), fig. 8 (222 C.G.S. Coll., now 7182 S.A. Mus.).

1925. *Dalmanites* (*Anchiopella*) *africanus* (Salter) sens. restr. Reed : Ann. S. Afr. Mus., vol. xxii, p. 122, pl. viii, figs. 1, 1a-c.

Non 1856. *Phacops africanus* Salter : Trans. Geol. Soc. Lond., ser. 2, vol. vii, p. 218, pl. xxv, fig. 1.

Non 1873. *Encrinurus cristagalli* Woodward : Q.J.G.S., vol. xxix, p. 31, pl. ii, figs. 6, 7.

Non 1906. *Phacops acacia* Schwarz : Rec. Alb. Mus., vol. i, p. 398, pl. x, figs. 4, 4a (2124 Alb. Mus.).

Non 1913. *Dalmanites* (*Mesembria*) *acacia* (Schwarz). Clarke : Foss. Devon. Paraná, p. 116, pl. v, figs. 5-9.

Material.—This species is erected for the bulk of the material which has hitherto been referred to the unsatisfactory species *Ph. africanus* Salter and *Ph. acacia* Schwarz. The writer has examined the specimens of "*Ph. africanus*" figured by Lake and Reed, as well as most of the other material mentioned by the latter.

Type Material.—In the collection of the Geology Department of the University of Cape Town are several parts of a large nodule (321 a-d) containing portions of at least two individuals. That these portions belong to one and the same species is indicated by their close association in one nodule and by the fact that the several portions can be identified with parts of other complete specimens. Since these are in some respects the best specimens that have yet been recovered, they are accordingly selected as co-types.

The nodule containing the co-types has been in the present collection for some time and is believed to have been found in the Hex River Pass area, but the place of origin is uncertain. In 1921 Mr. A. R. E. Walker exhibited it at a meeting of the Royal Society of South Africa, and some time ago it was sent to the British Museum for inspection. In his revision of the Bokkeveld fauna, Reed (1925B, p. 126) briefly described the specimen without giving figures.

The nodule contains the following specimens, all of them in a good state of preservation :—

- (i) External mould of a nearly complete, well-preserved thorax-plus-pygidium.
- (ii) Internal cast of the above.
- (iii) External mould of part of the thorax and almost the whole of the pygidium of another individual.
- (iv) Internal cast of the above.
- (v) Internal cast, slightly crushed, of the greater part of the cephalon,

showing most of the glabella, the meso-occipital segment with its median spine, and part of the left side of the cephalon. (This cephalon was exposed by development of part of the nodule and was not seen by Reed in 1925.)

These, together with a plaster-cast of the external moulds sent to Cape Town by the British Museum, are described below.

Description of Co-types.—The cephalon occurs in close association with the two individuals whose thorax-plus-pygidium are preserved, and most probably belongs to one or the other. The cephalon, though incomplete and with the glabella somewhat crushed from above, shows some of the characteristic specific features. Glabella moderately inflated, probably subpentagonal when complete; first two pairs of furrows very faintly impressed, the anterior pair somewhat oblique; third pair of furrows deeply impressed, the furrows extending inwards to about one-third the width of the glabella and limited on the outer ends by a slight coalescence of the second and third (basal) pairs of lateral lobes; basal lobes broad, well developed. Axial furrows broad, relatively shallow, almost straight. Neck furrow deeply impressed behind each of the basal lobes, but broad and very shallow in front of the nuchal spine. Meso-occipital segment strong, the central part merging gradually upwards into the stout, rapidly tapering median spine. Left eye large and prominent.

Dimensions of type cephalon: width of glabella across basal lobes 19 mm.; length of nuchal spine 5 mm.; width of base of nuchal spine 4 mm.

Thorax robust, gently tapering towards pygidium. Trilobation well marked; axial furrows broad, gently concave. Axis prominent, convex, slightly wider than the lateral pleural regions. Segments of the axis bearing a stout median spine, gently tapering above, with broad base. Pleurae divided longitudinally by a well-marked groove into a posterior convex rib and an anterior flattened, slightly swollen platform. Pleurae horizontal for about one-third of the distance from the axial furrows, then gradually bending downwards, sloping steeply to the margin of the thorax. Ends of the pleurae flattened, with a posteriorly directed angle or point.

Pygidium strong, convex. Width of first segment greater than length. Outline roughly triangular. Axis very prominent, convex, almost semi-circular in section, tapering very gradually; axis prominent from anterior right up to the posterior end of the pygidium; composed of nine distinct, slightly convex segments, separated by well-marked grooves, the segments becoming narrower but less distinct posteriorly. Pleurae very distinct but not reaching the lateral margins. Margin of pygidium entire, smooth, slightly convex antero-laterally, slightly concave towards the posterior.

Dimensions of specimen (i), thorax-plus-pygidium. Length of thorax

45 mm. Breadth of thorax at fifth segment 50 mm. and at eleventh segment 40 mm. Breadth of thoracic axis at fifth segment 19 mm. and at eleventh segment 15 mm. Length of axial thoracic spines about 8 mm. Length of pygidium 21 mm.

Remarks.—The well-preserved thorax-plus-pygidium described above agrees in every feature with the other (iii and iv) contained in the same nodule. Since both of these can be matched with other specimens whose cephalon is identical in all the observed features with the associated cephalon contained in the same nodule (v), the latter can safely be assumed to belong to the same species.

Additional information as to the structure of the cephalon is given by the specimen (I 4047 Br. Mus.) described and figured by Reed (1925b, p. 125, pl. viii, figs. 1, 1a-c) under the title *D. (Anchiopella) africanus* (Salter). Noteworthy is the almost pentagonal, moderately inflated glabella, obtusely angulated anteriorly and antero-laterally. The glabella furrows agree with those of the type in every respect, both as regards strength and position; the first two pairs being very faint, the first placed somewhat obliquely; the third pair being deeply impressed but shallowing towards the axial furrows. The stout base of the nuchal spine is clearly indicated, as are also the prominent eyes. As Reed has indicated, the attached thorax and pygidium agree in every respect with the specimen here selected as type and with Lake's *Ph. africanus* (1904, p. 205, pl. xxiv, figs. 6-8). The lateral parts of the cephalon of the British Museum specimen are, however, missing. The cephalon and thorax are finely granulated, coarsest on the glabella; in the type these are not preserved.

In no specimen have the genal angles been perfectly preserved, but attached to the almost complete internal cast (5420 S.A. Mus.) mentioned by Reed is part of the external mould of the left genal angle, which appears to have been broadly rounded without trace of a genal spine; on and below the margin represented by this mould are closely set, rather coarse tubercles.

It should be noted that Lake did not include in his *Ph. africanus* the original of Salter's figure five (1856, p. 218, pl. xxv, fig. 5), which was accepted as conspecific with the aforementioned specimens by Reed. This specimen (11287 Br. Mus.) is a small nodule containing a well-preserved fragment of a cephalon, showing the greater part of the glabella, the meso-occipital segment and spine, and part of the elevated right eye. It may be doubted whether this specimen belongs to *B. bokkeveldensis*, since the glabellar furrows are more strongly developed and almost subequal.

Bainella gamkaensis sp. nov.

Plate IX, figs. 14-17.

Holotype.—The species is based on a remarkable, almost complete, well-preserved, internal cast of a cephalon from the Basal Shales at Gamka Poort. S.A. Mus. 8977.

Description.—Cephalon wider than long, with remarkably swollen glabella and drooping cheeks. Glabella large, wider in front than behind. Glabellar furrows well marked; anterior and median pairs of furrows broad, concave, but comparatively shallow; anterior furrows placed somewhat obliquely; posterior pair of furrows shorter than the other two, deeply impressed, almost pit-like. First and second pairs of lateral lobes broad and convex; basal lobes shorter than the other two, narrow but elevated. Frontal lobe very swollen, almost hemispherical, evenly rounded, and slightly overhanging the anterior cephalic margin in front, obtusely subangular antero-laterally. Large, shallow, circular depression or pit placed centrally just anterior to the proximal terminations of the first pair of furrows. Margins of glabella very steep.

Axial furrows deep, U-shaped, diverging at about 35° . Fixed cheeks inflated behind and posterior to the eyes, sloping steeply towards the marginal rim. Eyes large, prominent, well elevated; lens-bearing surface long and curved. Well-defined, flattened, slightly convex marginal rim or platform on the lateral sides of the cephalon, with a corresponding wide, shallow, marginal groove running parallel to it within; rim and groove both becoming indistinct anterior to the eyes, but becoming very distinct in the neighbourhood of the genal angles. Facial sutures with anterior branches converging anteriorly from the eyes and joining round the base of the overhanging frontal lobe; posterior branches nearly horizontal from eyes to marginal rim, then curving back sharply.

Occipital furrow strongly developed, broad and U-shaped on the fixed cheeks, bending round sharply within the genal angle to meet the marginal furrow at about $65-70^{\circ}$. Occipital segment broad near the genal angle and bending round sharply to meet the marginal rim. Meso-occipital furrow strongly developed, U-shaped in front of the nuchal spine, with deep pits behind the basal lobes of the glabella. Meso-occipital segment moderately prominent, arched, bearing a short median spine. Genal angles not produced posteriorly, subrectangular (possibly pointed at the angles?).

Marginal rim continued anteriorly as a narrow rib immediately below the anterior part of the facial suture. Rostral doublure gently rounded, convex, and slightly upturned in front.

All parts of cephalon covered with fine, scattered, but very distinct tubercles.

Length 34 mm. Distance from nuchal spine to genal angle about 32 mm. Width of glabella across frontal lobe 28 mm., across basal lobes 18 mm.

Remarks.—This species, so distinct on account of the remarkable inflation of the anterior part of the glabella, should undoubtedly be placed in the new genus *Bainella*. The lobation of the glabella is of essentially the same type as that of the type species described above; attention is drawn especially to the compactness of the glabella as a whole, the relative weakness of the anterior and median pairs of furrows, and the deep basal furrows. Other noteworthy points of agreement are the presence of the well-developed nuchal spine in each species, the absence of a strong posterior extension of the genal angle, the narrow frontal margin, and the fine granulation of the surface. The subpentagonal outline of the glabella, so characteristic of *B. bokkeveldensis* and *B. baini*, is obscured by the greater inflation of the frontal lobe.

Bainella sp.

Plate IX, fig. 18.

Material.—From the Basal Shales at Gamka Poort comes the cephalon described below, incomplete, but with the glabella well preserved. S.A. Mus. 8976.

Description.—Cephalon considerably wider than long. Glabella sub-pentagonal, compact, moderately inflated. Glabellar furrows well marked; anterior pair of furrows long, placed obliquely, commencing near but posterior to the rounded antero-lateral angles; posterior pair of furrows slightly deeper than the other two. Basal lobes elevated, rather narrower than the anterior and median lobes. Frontal lobe moderately inflated, wider than long, obtusely angulated in front. Axial furrows well marked. Frontal margin narrow, showing very distinctly the broken base of a frontal spine. Meso-occipital segment strong, somewhat arched, showing very distinctly the broken base of a nuchal spine; meso-occipital furrow distinct, deepened behind the basal lobes. Eyes probably large and elevated. Pleuro-occipital segment narrow but moderately elevated, with a deep pleuro-occipital furrow. Genal angle apparently bearing a posteriorly directed point.

Surface of glabella covered with scattered coarse tubercles with little trace of regular arrangement. One or two coarse tubercles are present on the crests of each of the glabellar lobes, and tubercles are present at intervals on the meso- and pleuro-occipital segments.

Remarks.—This cephalon represents a species distinct from but probably closely allied to *Ph. arbuteus* Lake (1904, p. 203, pl. xxiv, fig. 2, *non* figs. 3, 4) (64 Cape Geol. Surv. Coll., now 7181 S.A. Mus.) from the same locality

and probably also from the Basal Shales. The latter is based on a large distorted glabella which agrees in all essential features with that described above. In both cephalae the glabella is remarkably compact, about as wide as long, subpentagonal, with subequal furrows and oblique anterior furrows. In both cephalae the frontal lobe and axis of the glabella are covered with stout scattered tubercles, which occur also on the lateral lobes and meso-occipital segment, and both cephalae are characterised by the presence of a nuchal spine. The new specimen differs from *Ph. arbuteus* Lake in that the tubercles are less coarse and more numerous; in the latter the tubercles are particularly coarse between the lateral lobes, where they are arranged in two rows; in the former the tubercles are more numerous and irregularly disposed between the lateral lobes on the axial part of the glabella.

It should be remarked that Lake's second cephalon (*ibid.*, fig. 3) (61 Cape Geol. Surv. Coll., now 9606 S.A. Mus.), also from Gamka Poort, is not very well preserved, and Reed (1925b, p. 128) has rightly shown that it lacks the characteristic coarse tubercles of the type of *Ph. arbuteus*. Reed (1925b, p. 148) was inclined to associate the specimen with *Phacops* (*Cryphaeus*) *ceres* Schwarz, on the grounds that there is no clear evidence of a nuchal spine; but there is on the same slab a mould of a similar cephalon in which the spine is quite evident, so that a position near *Ph. arbuteus* seems to be justified.

GENUS TYPHLONISCUS Salter.

Typhloniscus baini Salter.

Plate X, figs. 6-12.

1856. *Typhloniscus Bainii* Salter: Trans. Geol. Soc. Lond., ser. 2, vol. vii, p. 221, pl. xxv, fig. 14 (11292 Br. Mus.).
1904. *T. baini* Salter. Lake: Ann. S. Afr. Mus., vol. iv, p. 213, pl. xxv, figs. 8, 9 (41 C.G.S. Coll., now S.A. Mus., and 63 C.G.S. Coll., now 7186 S.A. Mus.).
1913. *T. Baini* Salter. Clarke: Foss. Devon. Paraná, p. 158.
1925. *T. Baini* Salter. Reed: Ann. S. Afr. Mus., vol. xxii, p. 162.
1927. *T. baini* Salter. Reed: Geol. Mag., vol. lxiv, p. 347.

Material.—The holotype (11292 Br. Mus.) of this remarkable species is incomplete, for the pygidium is missing and the cephalon is somewhat damaged; the specimen has undergone a certain amount of lateral compression, resulting in a distortion of the cephalon and a deepening of the axial furrows. The Bain Collection in the British Museum contains a second specimen (11302 Br. Mus.), identified by Salter and Reed with the type but not figured, in which the pygidium can be made out, but the

specimen is very weathered. The examples figured by Lake are incomplete and immature. The new material from Gamka Poort includes several fine specimens, thus rendering possible a complete diagnosis of the species for the first time. This includes :

- (i) Internal cast of a complete individual.
- (ii) Nodule containing fine internal casts of a cephalon and a pygidium, presumably belonging to the same individual.
- (iii) Internal cast of cephalon, somewhat worn.
- (iv) Internal cast of a pygidium.
- (v) External mould of a cephalon.
- (vi) External mould of a cephalon-plus-thorax.

These were all found in the Basal Shales at Gamka Poort.

Description.—Cephalon semicircular, about half as long as wide. Glabella somewhat depressed, broad, widening gradually anteriorly, rounded or slightly subangular in front. Furrows unequally developed. First pair of lateral furrows shallow, commencing on either side of the axis just behind the middle, directed obliquely forwards. Second and third pairs of furrows deeply excavated, rather short, barely entering the axial furrows. Lateral lobes well defined by the furrows, the basal lobes slightly narrower than the others. Frontal lobe gently convex, pointed laterally. Occipital furrow well defined, excavated on either side of the axis. Meso-occipital segment swollen; pleuro-occipital segments widening laterally. Axial furrows broad and shallow. Cheeks swollen, subtriangular, separated from the distinct marginal rim by a broad but shallow marginal furrow. Doublure separated from the dorsal surface by a well-marked suture-like groove, which runs along the upper side of the rounded marginal rim for the greater part of its length, but becomes infra-marginal towards the genal angles. Anterior part of doublure forming a rounded infra-marginal band, which is recessed opposite the axial furrows and arched forward in front of the cheeks. Facial sutures absent. Eyes absent, possibly represented by a large tubercle or swelling at the extreme front of each cheek. Genal angles slightly produced.

Surface of cephalon covered with scattered coarse pits, which are particularly coarse on the swollen cheeks.

Thorax narrowing rapidly posteriorly. Axis prominent, rather narrow. Pleurae straight and horizontal for a distance about equal to the width of the axis, and then bent backward and somewhat downward, the fulcrum being well marked but rounded. Pleurae deeply grooved, the anterior part less prominent than the posterior part. Pleurae pointed at the ends.

Pygidium comparatively small, wider than long, rounded, with entire margin. Axis very prominent, maintaining the same height and width

throughout, abruptly truncate and slightly overhanging posteriorly. Axis with four prominent swollen segments and traces of a fifth segment at the posterior end. Lateral parts of the pygidium depressed, with three extremely prominent, convex, laterally compressed pleurae, and a fourth, smaller, tubercle-like pleura, on each side. First three pleurae subequal and placed obliquely to the axis.

Remarks.—It must be pointed out that the external moulds show that the ornamentation of this remarkable aberrant species consists of coarse pits, not tubercles as previously described. Reed (1925b, p. 163) has described a fine tuberculation of the infra-marginal part of the doublure in a specimen in the Albany Museum (2561 Alb. Mus.).

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EXPLANATION OF PLATES.

(Figures approximately natural size unless otherwise stated.)

PLATE IX.

Dalmanites (Metacryphaeus ?) ceres (Schwarz).

1. Holotype; Alb. Mus. 67.
2. Paratype; Alb. Mus. 27.

Dalmanites (Metacryphaeus) aff. caffer (Salter).

3. One of the co-types of *D. (Corycephalus ?) capensis* Reed, seen obliquely to show the line of fracture passing beneath the right eye; Cape Town Univ. Coll. 216; Touws River Road, Hex River Valley.
4. Same specimen, dorsal view, showing the misplaced position of the right cheek.

Acaste (Pennaia) impressus (Lake).

5. Topotype; S.A. Mus. 8969a.
6. Cephalon of holotype, with part of enrolled thorax; S.A. Mus. 7187; Gamka Poort.
7. Topotype; S.A. Mus. 8959.
8. Topotype; S.A. Mus. 8961.
9. Topotype; S.A. Mus. 8963.
10. Topotype; S.A. Mus. 8967.
11. Holotype of *Phacops gydowi* Schwarz; Alb. Mus. 28; Gydo Pass, Ceres.
12. Topotype; cephalon with anterior border more rounded than in the holotype, associated with pygidium with a small fourth right marginal spinule; S.A. Mus. 8966.
13. Topotype; juvenile cephalon from same nodule as fig. 5, showing distinct left genal spinule; $\times 2.3$; S.A. Mus. 8969c.

Bainella gamkaensis sp. nov.

14. Holotype; dorsal view; S.A. Mus. 8977; Gamka Poort.
15. Holotype; from left side.
16. Holotype; view of doublure.
17. Holotype; anterior view.

Bainella sp.

18. Cephalon, dorsal view; S.A. Mus. 8976; Gamka Poort.

Acaste (Calmonia) callitris (Schwarz).

19. Holotype; Alb. Mus. 29; Cedarbergen.

PLATE X.

Bainella bokkeveldensis sp. nov.

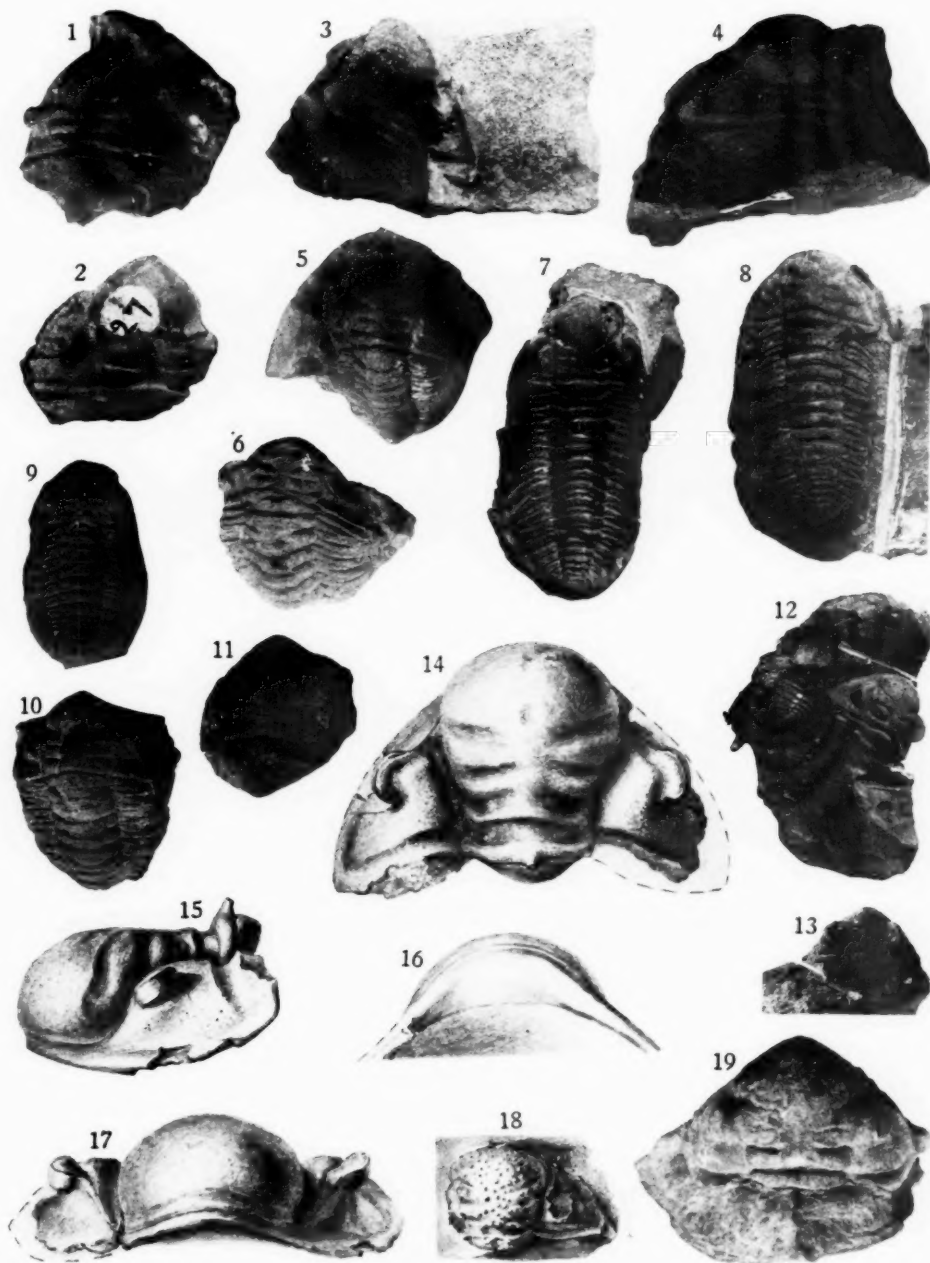
1. External mould of the type thorax and pygidium with part of the mould of another thorax; Cape Town Univ. Coll. 321a.
2. Internal cast of the type thorax and pygidium; Cape Town Univ. Coll. 321b.
3. Internal cast of type cephalon; Cape Town Univ. Coll. 321d.
4. Rough plaster-cast of the same specimen as fig. 1.

Bainella acacia (Schwarz).

5. Holotype; *a*, position of eleventh thoracic segment; *b*, position of seventh thoracic segment; *c*, position of nuchal spine; *d*, part of right eye; *e*, position of genal spine; Alb. Mus. 2124.

Typhloniscus baini Salter.

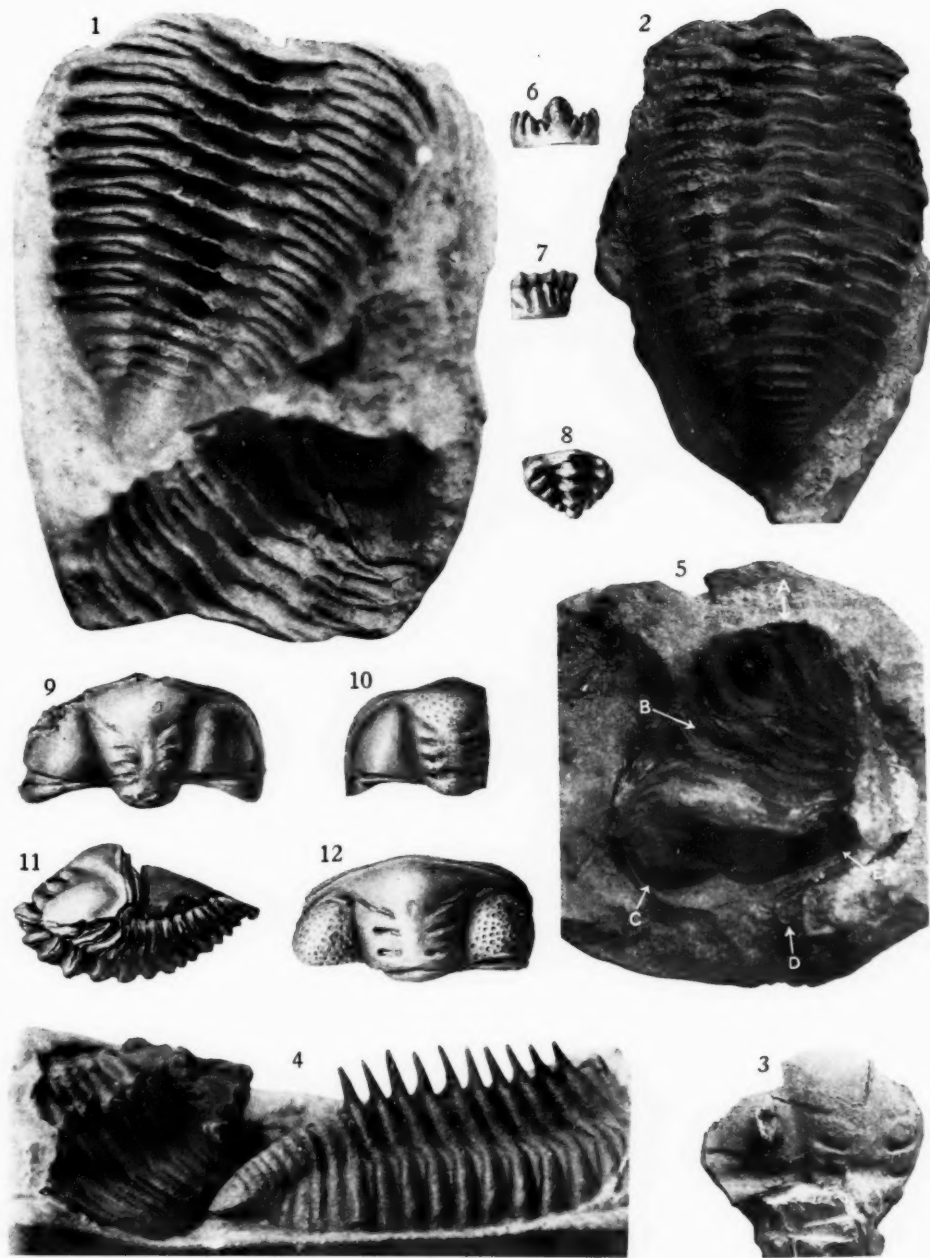
6. Internal cast of pygidium from same nodule as cephalon of fig. 10, posterior view.
7. Same pygidium, from left side.
8. Same pygidium, dorsal view.
9. Cephalon, poorly preserved internal cast; S.A. Mus. 8980; Gamka Poort.
10. Cephalon, internal cast, from same nodule as the pygidium of figs. 6-8, dorsal view; S.A. Mus. 8982; Gamka Poort.
11. Complete enrolled individual, from right side; S.A. Mus. 8983; Gamka Poort.
12. Plasticene cast of external mould of cephalon, dorsal view; S.A. Mus. 8978; Gamka Poort.



E. T. Talbot, del. et W. Rose, phot.

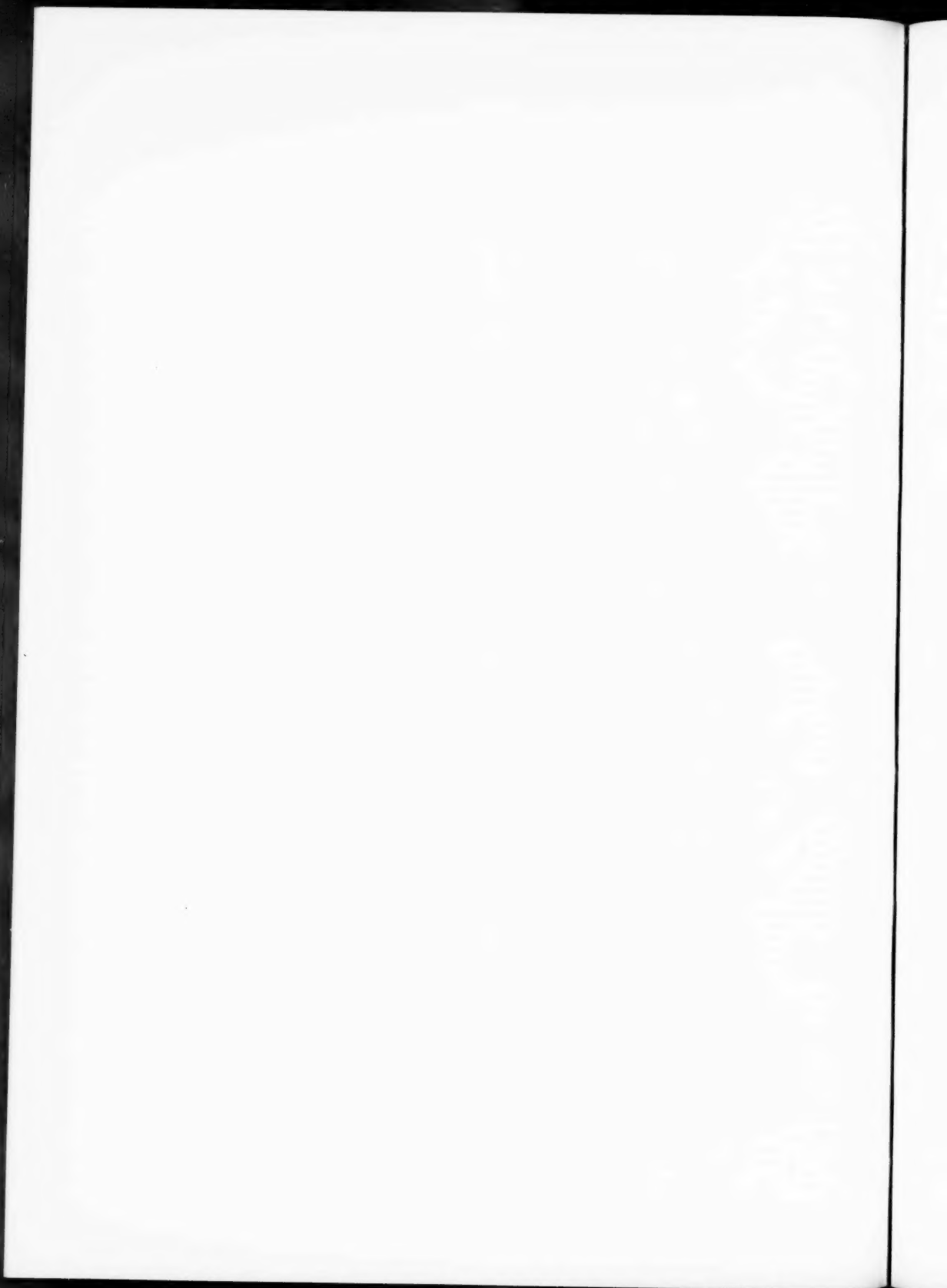
SOME PHACOPIDAE FROM THE BOKKEVELD SERIES.





E. T. Talbot, del. et W. Rose, phot.

SOME PHACOPIDAE FROM THE BOKKEVELD SERIES.



ON THE OCCURRENCE OF UPPER CRETACEOUS MARINE
FOSSILS NEAR BOGENFELS, S.W. AFRICA.

By S. H. HAUGHTON, D.Sc., F.G.S.

(Published by permission of the Hon. the Minister for Mines and Industries.)

(With Plate XI.)

Thanks to the courtesy of the manager and officials of the Consolidated Diamond Mines of South-West Africa, the writer was recently enabled to make a short tour of the diamondiferous coastal area of the Namib between Pomona and the mouth of the Orange River in company with Dr. A. L. du Toit and Dr. Knetch; and, whilst examining the fossiliferous marine outcrops north of Bogenfels, he was fortunate enough to discover a specimen of an Ammonite. This discovery, made in beds that have been hitherto almost universally regarded as Tertiary, is sufficiently interesting to merit record.

The first fossils from Bogenfels were discovered by Klinghardt who, as recorded by Lotz (1913), made a small collection and showed the locality to the surveyor Schettler. Through the latter Dr. Merensky made a collection in January 1909, but it is uncertain whether these specimens actually came from Bogenfels. Merensky, however, identified the following species *Protocardium hillanum*, *Zaria bonei*, and *Turritella meadi*—all forms found in the Senonian of Pondoland. Dr. Reuning and Dr. Lotz made further collections in July 1909, and, on the basis of these, Böhm and Weissermel in 1913 published their paper, "Ueber tertiäre Versteinerungen von den Bogenfelder Diamantfeldern," in which the age of the fossils was determined as Miocene.

Considerable collections were made by Dr. Kaiser and Dr. Beetz during 1914-1919, and were later studied by Böhm, who revised his former conclusion and decided that the age was Middle and Upper Eocene.

This most recent discovery of an Ammonite, however, which is obviously an original member of the fauna and not a rolled derived fossil, raises anew the question of the age of the marine beds of Bogenfels and the possibility that two sets of sediments are present in this locality.

The general position and nature of the fossiliferous beds in the Bogenfels area have been well described by Lotz and, later, by Beetz. The following

observations were made by the writer during his very short visit there and cannot pretend to do more than supplement, from the point of view of this new discovery only, the details given by those who have spent weeks or months in studying the stratigraphy.

The locality visited lies just to the east and north-east of Wanderfeld IV, north of the old Bogenfels Station, and is a small depression running into the Langental. The rocks below the fossiliferous series are schists and blue dolomites of the "Hauptdolomit." The basal bed of the marine series is a coarse shingle-bed dipping to the south, composed mainly of quartzite pebbles; but, although search was made, no pebbles of Pomona quartzite were found in this basal shingle. (The Pomona quartzite caps the hills at a much higher level south of the Luderitzfelder and also at Zwartkuppe to the east-south-east.) Directly above the shingle, at a height above sea-level of 70 metres, are fossiliferous beds with very numerous specimens of *Turritella* and *Mastra* occurring in brownish ferruginous sandy-marly concretions in a greenish sandy bedded deposit which itself contains numerous *Ostrea*. Above the *Ostrea* bed are a few feet of unfossiliferous greenish fine-bedded sandy clays with irregular siliceous concretionary veins. No continuous sections of the beds is seen; but at a spot a few hundred yards to the south, and at a height of 60 metres above sea-level, occurs a rich shelly limestone with abundant *Exogyra*, in which was found the Ammonite described below.

The exact relationship between this *Exogyra* bed and the *Turritella* beds higher up the valley is a matter at present of conjecture only. The only positive piece of evidence obtained was the discovery by Dr. du Toit of a band of coarse felspathic grit a few feet up the slope from the *Exogyra* bed. This may be the equivalent of the shingle at the head of the valley and thus indicate that the *Turritella* beds overlie the *Exogyra* Zone, and possibly unconformably. Further exploratory work, including trenching, is necessary before that point can be settled.

The only fossils hitherto collected from these *Exogyra* beds are fairly numerous valves of *Exogyra* and the single specimen of an Ammonite, which must be placed within the genus *Placenticeras*. Brief notes upon these follow.

Exogyra cf. *columba* (Lamarek).

Several isolated left valves of varying size show features that cause them to be placed almost certainly in this well-known Cenomanian species. The specimens are slightly variable in shape, but agree in being higher than long and inflated, in having an umbo that is prominent, spiral, curved backwards, and with its point—in the best preserved specimens—free. They agree also in the regular convexity of the flank, only the small speci-

mens showing a trace of a rounded carina extending from the umbo postero-ventrally. The postero-dorsal part of the valve, near the umbo, is concave. The surface of the valve is smooth except for growth lines, and except where subsequent differential weathering of the shell surface has produced a coarse pustulation. This, however, is not an original feature.

The greatest similarity is thus shown with *E. columba* var. *silicea* Lamk., as defined by Pervinquière. From the higher-zone form *E. overwegi* the shells are definitely separated by the absence of any sign of radial costae, even on the umbonal region.

It is interesting to note that not one of the specimens collected can be associated with *E. scheibei* Böhm from the *Turritella* beds.

Placenticerus merenskyi sp. nov.

This is an adult shell with the body whorl partly preserved and has the following measurements, taken approximately at the plane of the last suture :—

			<i>P. subkaffrarium.</i>	<i>P. reineckeii.</i>
Diameter	112 mm.			
Thickness	32 „ =29 per cent.		37 per cent.	30 per cent.
Height of Whorl	54 „ =48 „		50 „	49 „
Umbilical Width	20 „ =18 „		15 „	15 „

(For comparison the percentages of *subkaffrarium* from Zululand and *reineckeii* from Angola are given.)

The chief ornamentation consists of very small umbilical tubercles, of which there are about twelve in the last whorl. The venter is narrow, the lateral ridges becoming obscure in the body whorl, and the nodes on the lateral ridges being very inconspicuous. The external features of the lateral surface are not well displayed, but faint broad lateral folds can be discerned.

The suture is moderately frilled. The saddles are slightly larger than the lobes. The lateral lobes increase in size up to the third, which is deep ; and the fourth lobe is notably smaller and more reduced than its predecessors as in *Proplacenticerus*.

The specimen differs considerably from the Senonian *subkaffrarium* from Zululand and *reineckeii* from Angola, although its measurements approximate to those of the latter. The sides are less swollen than in these two species, the umbilical tubercles are more numerous and less prominent, and the ventral tubercles much less conspicuous.

The former comprehensive genus *Placenticerus* has been split into a number of genera by more recent workers, and comparisons must be made between some of these and our form. From *Hypenogoceras warthi* (Cenomanian of Madagascar) the Bogenfels fossil is distinguished by its larger

umbilicus and by its suture-line. *Metaplacenticerus* is a genus that seems to be confined to Western America and, although agreeing with our form in the size of its umbilicus, is sharply marked off by its strong sculpture. *Proplacenticerus* also seems to be distinct from our form, although its suture-line agrees fairly closely.

From the Cenomanian *Knemiceras* the species is sharply differentiated.

In his discussion of the genus *Placenticerus*, Hyatt stated that the species known to him were all connected so closely by intermediate forms that distinct lines were difficult to draw between contiguous species. Nevertheless, this shell from Bogenfels seems so distinct from any other *Placenticerus* described from Africa that a new specific name seems advisable, and the name *Placenticerus merenskyi* is proposed, in honour of Dr. H. Merensky who first drew attention to the occurrence of Cretaceous deposits in this area.

Occurring as they do in the same block of matrix, there can be no doubt that these two forms are of the same age; but the evidence from one does not agree with that from the other. *E. columba* is typically a Cenomanian species; the group of Placenticeratids to which *merenskyi* seems to belong do not occur lower than the Coniacian, the Cenomanian and Turonian forms belonging to different genera, as indicated above. Moreover, as far as the writer can see, *P. merenskyi* does not show features in its adult stage that could be interpreted as juvenile features of the genus, and it would therefore seem not possible to place it any earlier than the Lower Senonian. If that be accepted, then it becomes necessary to look upon the *Exogyra* as a species that has closely simulated *E. columba* or to extend the range in time of that species.

The discovery of Upper Cretaceous marine fossils as far south as latitude 27° 24' is a matter of considerable interest. In most discussions of the history of the African coast-line it has hitherto been assumed that the so-called "Angola Gulf" extended, in Lower and Upper Cretaceous times, from the Tethys Sea as far south as Benguella in Angola; and that south of this lay the Brazilio-African continent.

In the latest discussion of the subject, however, Rennie (1929) concludes that "the great Campanian transgression, which left deposits in Pondoland, Zululand, Angola, and elsewhere, opened up a sea connecting the Angolan Gulf with the southern ocean, and thus permitted intermingling of 'Atlantic' and 'Indo-Pacific' elements in Angola and South-East Africa. . . . One is tempted to suggest that the communication may have been established as early as the Coniacian."

Although this new discovery gives no further evidence for or against the supposition that the Cretaceous Indo-Pacific Ocean joined the "Angola Gulf" along the western coast of Africa, it does show definitely that the "Gulf" was of much greater extent than has hitherto been supposed, and



FIG. 1.

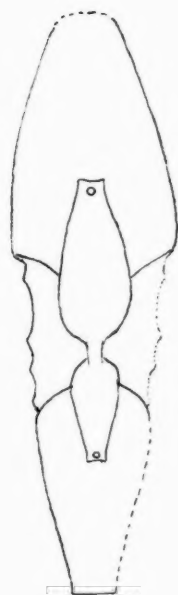
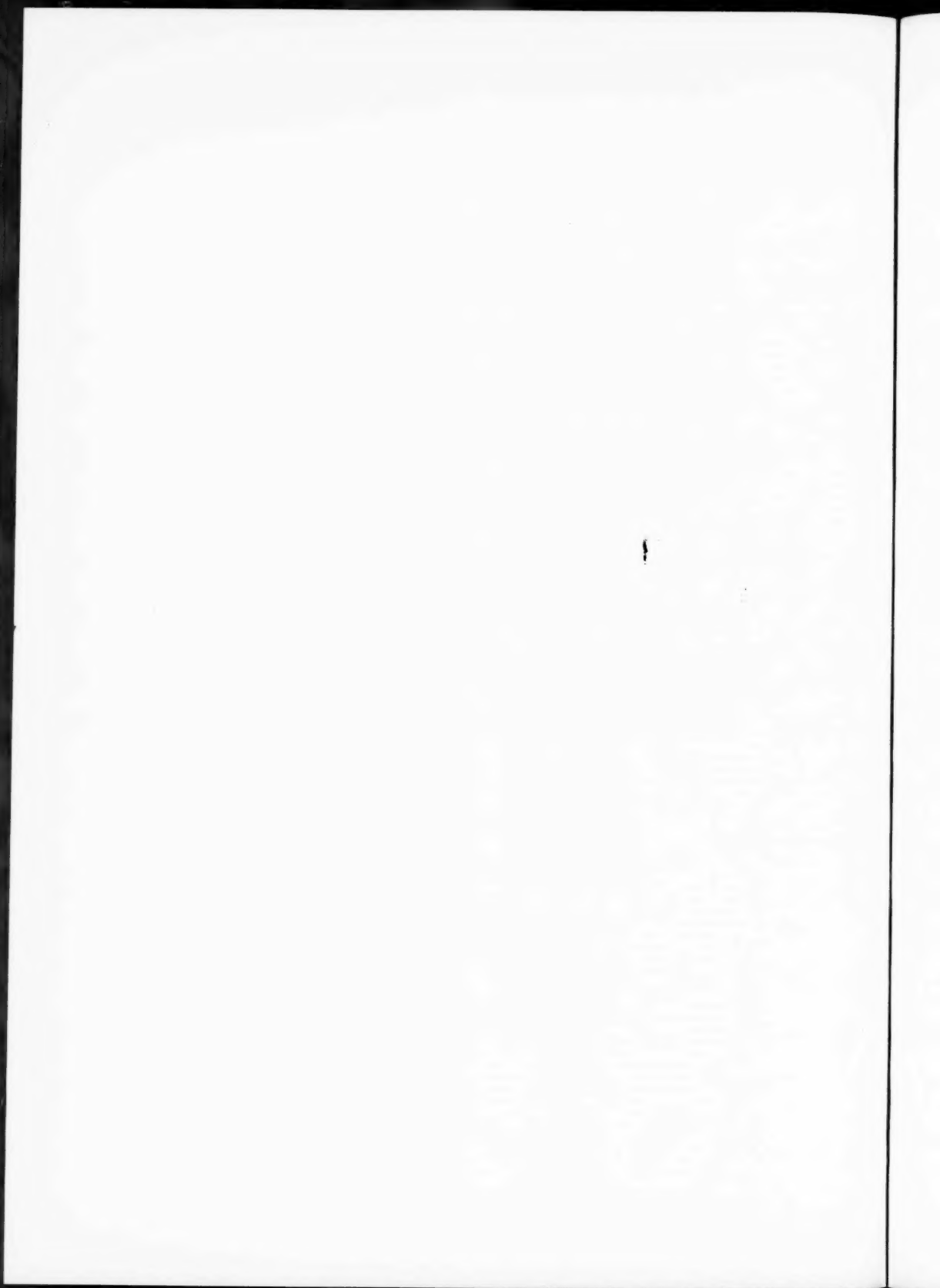


FIG. 2.



FIG. 3.

Placenticerus merenskyi sp. nov. Haughton.



opens up the possibility of yet further discoveries of the same nature being made more to the south. It is highly probable, too, that the marine Cretaceous of Bogenfels is contemporaneous with the continental deposits in Bushmanland which yielded the Dinosaur *Kangnasaurus*.

There remains to be considered the relation of these marine beds to the continental Pomona quartzite, which Beetz has tentatively assigned to the Upper Cretaceous and which has hitherto yielded but one land-shell, *Dorcasia antiqua*. As Beetz has shown, the Pomona beds of the Namib occur as outliers capping hills, but were obviously deposited upon an uneven surface. He definitely places their age as pre-Middle Eocene, considering that at numerous places they are overlain by Eocene, or the Eocene beds contained rolled fragments of the quartzite. It is to be noted, however, that at no place where the beds mapped as Eocene show definite relations to the Pomona quartzites have fossils been obtained; that at Bogenfels the basal shingle of the fossiliferous *Turritella* beds was not found to contain pieces of the quartzite; and that in this area the outliers of Pomona beds occur at a higher level than the marine deposits. It is possible, therefore, that the Pomona quartzite has a later age than that assigned to it by Beetz, and that the supposed Eocene beds north-east of Advokaten, at the Eisenkieselklippenbake (east of Bogenfels), and at the so-called Luderitzkrater must be placed later in the Tertiary. Until more fossil evidence is forthcoming, these matters must remain in doubt. It is to be hoped that more work will be done particularly upon the Bogenfels deposits in order to ascertain the exact relationship between the *Exogyra* beds and the *Turritella* beds, to connect up these with the mammal-bearing beds to the south, and to augment the number of species from the *Exogyra* beds.

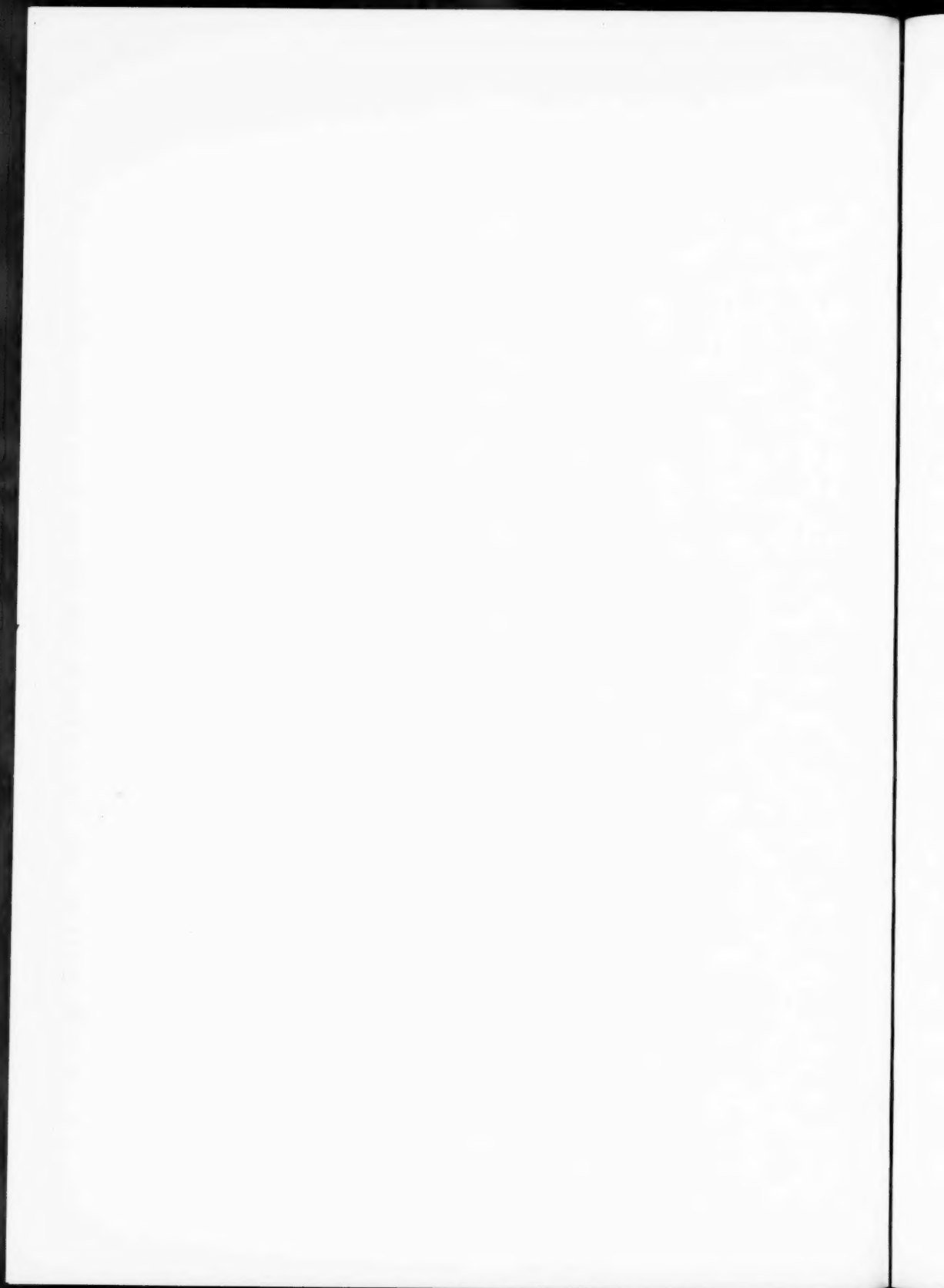
EXPLANATION OF PLATE XI.

Platoniceras merenskyi sp. nov. Haughton, from Upper Cretaceous of Bogenfels, South-West Africa.

Fig. 1. Lateral view of type.

Fig. 2. Cross-section of type. Inner whorls not seen owing to lack of preservation of outline in crystalline calcite.

Fig. 3. Final suture-line of type.



TRANSACTIONS
OF THE
ROYAL SOCIETY OF SOUTH AFRICA.
VOL. XVIII.

MINUTES OF PROCEEDINGS.

ANNIVERSARY MEETING.

The Anniversary Meeting of the Society was held on Wednesday, March 21, 1928, at 8 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. A. OGG, was in the Chair.

The Report of the Hon. General Secretary was submitted and adopted.

The Report of the Hon. Treasurer was submitted and adopted.

The following Fellows were elected members of the Council for the year 1928 :—

Dr. R. S. ADAMSON.

Dr. C. F. JURITZ.

Dr. B. DE ST. J. VAN DER RIET.

Dr. J. SMEATH THOMAS.

Dr. H. B. FANTHAM.

Mr. C. M. STEWART.

Dr. J. W. C. GUNN.

Dr. A. L. DU TOIT.

Dr. S. H. HAUGHTON.

Dr. W. A. JOLLY was elected President.

Dr. L. CRAWFORD, Hon. Treasurer.

Dr. A. OGG, Hon. General Secretary.

On the motion of the President it was resolved to send a letter of sympathy to Mrs. EDIE on the death of her husband, Professor E. S. EDIE.

The President delivered the Presidential Address on "Some Aspects of Modern Physics."

After defining the general scope of physics, certain physical phenomena

VOL. XVIII, PART II.

a

and theories which had appealed to the popular imagination were referred to. It was pointed out that the principle of relativity had appealed to the imagination because it seemed to uproot firmly established notions.

The principle of relativity was first discovered by Lorentz, but Einstein was the first to proclaim it as a general principle. Einstein, by a brilliant piece of mathematical analysis, formulated a law of gravitation which gave Newton's law as a first approximation and made certain predictions which have been experimentally verified.

The origin of the quantum theory propounded by Professor Planck, and how the theory upsets the usual notions of the wave theory of radiation, were dealt with. The explanation is that ordinary mechanics give a satisfactory method of treatment for matter in bulk, but need amendment in specialised regions. The discontinuity of radiation is associated with the discontinuity of electricity and the part played by the units of electricity in atomic structure.

It has been generally accepted that the material universe is composed of atoms, and that the atoms are built up of positive and negative electrical units called protons and electrons. It was the scattering of alpha particles given off from radioactive substance by matter that led Rutherford to propound the nuclear theory of the atom, according to which the atoms of matter consist of a massive nucleus carrying a positive charge surrounded by planetary electrons, which are at great distances from the nucleus compared with the diameter of the electron.

This atom, however, is incapable of explaining the spectral lines characteristic of the atom.

In 1913 Dr. Niels Bohr discarded ordinary mechanics and substituted Planck's quantum relations to explain the radiations. Bohr's theory has met with great success in explaining many physical phenomena, especially optical and X-ray spectra. The extension of Bohr's theory by Sommerfeld and others has led to an insight into the physics of the atom which seems almost incredible, and has turned spectroscopy from a heterogeneous collection of miscellaneous facts into a rapidly advancing science.

Several difficulties were referred to, and how consideration of these difficulties had led atomic physicists to look for a departure from the point of view of Bohr, Sommerfeld, and their followers.

From principles of mechanics laid down by Hamilton more than 100 years ago it can be shown that the motion of a particle in a field of force can be represented as a ray of a propagated wave surface. The motion of a particle can be regarded as a wave with energy travelling along certain rays, the paths of the particles. A wave theory of the motions of electrons in atoms has been developed along this line by L. de Broglie. The electron is regarded as a train of waves whose group velocity is the velocity of the

electron. Just as the corpuscular theory of light breaks down when the obstacles and apertures become comparable with the wave-length, so the particle theory of dynamics breaks down when the distances concerned are of atomic dimensions. The reason is the same in both cases, namely, that both are wave phenomena, and in each case the dimensions concerned become comparable with the wave-length.

A wave theory of mechanics which coincides with Hamilton's principles on the large scale and true down to atomic dimensions has been developed by Schrodinger. The wave theory has, however, to face the difficulty of explaining the atomicity of matter and electricity.

In determining atomic structure the determination of the nuclear mass is of fundamental importance. Aston, by the mass spectrograph, has been able to determine nuclear masses correct to 1 in 10,000 and to separate the elements into elementary constituents. The mass defects in building the nucleus from protons and electrons have also been determined, and hence the energy radiated and the stability of the nucleus.

Rutherford's recent picture of radioactive elements with neutral satellites explaining radioactive radiations and the origin of gamma rays was briefly explained.

ORDINARY MEETING.

An Ordinary Meeting was held after the Anniversary Meeting.

Business :—

The Minutes of the last Meeting were confirmed.

Dr. PETRONELLA VAN HEERDEN was elected to Membership of the Society.

The Hon. Treasurer reported that a memorial to the late Dr. PERINGUEY, agreed to by the Council, put up at the South African Museum, of which he was Director at the time of his death, was unveiled by the Hon. Dr. MALAN, Minister of the Interior, on Friday, March 9, 1928.

The cost of this memorial was provided by the Museum, the Royal Society of South Africa, and members of the Society who had personally known Dr. PERINGUEY. The Hon. Treasurer said that it was not proposed to publish a list of the subscribers as subscriptions had only been asked for privately. No public appeal had been made to members.

Members who had been asked to subscribe had done so willingly towards the memorial to one who had done so much for the Society. Dr. L. PERINGUEY was one of the members most active in obtaining the grant of a Royal Charter to the Society.

KENILWORTH METEOROLOGICAL STATION.—It was reported that Dr.

SUTTON was leaving South Africa in a short time and that probably the Meteorological Station carried on by him would be closed down. It was resolved to refer the matter to the Council to take what action they thought proper.

NOTICE OF MOTION.—That a Committee of this Society be appointed to consider the formation of a Meteorological Society for the Union.—Professor E. NEWBERRY.

Communications :—

"The Essential Oil of *Agathosma microphylla*," by J. L. B. SMITH and K. A. C. ELLIOTT.

Agathosma microphylla, or "Stembok Buchu," is a short, stunted shrub which grows in patches on the seaward side of the coastal hills, being found fairly extensively about Knysna and in neighbouring districts. The shrub gives off a strong, aniseed-like odour which is very noticeable in the still valleys where it flourishes.

The oil content of the dried leaves appears to vary with the season, for 2 to 3 per cent. of volatile oil when collected in summer, and as much as 5 per cent. when collected in winter. 45 lbs. of air-dried leaves collected at various times yielded by distillation in steam 795 grams of a clear, yellow oil of powerful odour, the chief constituent of which is methyl chavicol.

Analysis has shown that the essential oil of *Agathosma microphylla* is made up of the following :—

Terpene Hydrocarbon, probably Myrcene	3 per cent.
Alcohols : $C_{10}H_{18}O$ in part, probably l-Linalool	30 "
Phenols, Eugenol	1 "
Phenol Ethers, Methyl Chavicol, and possibly Anethole	50 "
Esters : possibly $C_{10}H_{17}OCOCH_3$	4 "
Residue Sequiterpenes, losses, etc.	12 "

"Note on $(n-1)$ -by- n Arrays whose Primary Minors have a Common Factor," by Sir THOMAS MUIR, F.R.S.

"Observations on the Reproduction and Fungal Endophytism of *Lunularia cruciata* (L.) Dumortier," by THEODORA B. AURET, M.Sc. (communicated by Dr. C. E. Moss).

Female plants of *Lunularia cruciata* (L.) Dumortier are found in South Africa on slightly alkaline soil. Male plants and the sporophyte generation are not known. The gametophyte harbours a fungus which is confined to a definite zone below the assimilating tissue. The fungus in the liverwort consists of a number of branched septate hyphae with granular contents. No fructifications of the fungus have been found in the tissue. The fungus has been isolated and identified as a species of *Phoma*. The association between the liverwort and the fungus is not a case of true

symbiosis, but rather one of harmless parasitism. The fungus presents some striking contrasts from that found in another liverwort, *Pellia epiphylla* (L.) Corda.

"Contributions to our Knowledge of the Freshwater Algae of Africa. VII. Freshwater Algae (exclusive of Diatoms) from Griqualand West," by F. E. FRITSCH and FLORENCE RICH (communicated by Miss E. L. STEPHENS).

This is the first account of the algal vegetation of Griqualand West. (The diatoms, which are very numerous, are being dealt with in a separate paper.) 183 species are recorded, 33 of which are new or represented by new varieties, and the total number of genera represented is 69, of which one is new (*Raphidiopsis*, a member of the *Rivulariaceae*). There are 112 new records for South Africa of species or varieties. Particular interest attaches to the discovery of two new species of *Sphaeroplea*; *S. annulina*, the type of the genus, is also present. Other points of special taxonomic interest are the discovery of another species of the hitherto monotypic genus *Centritractus*, and a highly peculiar new *Phacus*, *P. anomala*.

"Demonstration of Three Freshwater Invertebrates found on the Cape Flats," by K. H. BARNARD.

Specimens of the freshwater Sponge (*Ephydatia fluviatilis* var. *capensis*), Polyzoon (*Plumatella repens*), and *Hydra vulgaris* were exhibited.

The communication on "Some Organisms Isolated from *Xenopus laevis*," by TH. SCHRIRE, was held over till next meeting.

A. OGG,
Hon. General Secretary.

REPORT OF THE HON. GENERAL SECRETARY FOR 1927.

Eight Ordinary Meetings, the Annual Meeting, and the Anniversary Meeting were held during the year, and the undermentioned papers were read:—

1. "On *Xysmalobium undulatum*: A Chemical and Pharmacodynamical Study of 'Chonga' (Bitter-wortel)," by J. M. WATT and MARIE G. BRANDWIJK.

2. "The Comparative Anatomy of the Breast-shoulder Apparatus of the three Aglossal Anuran Genera, *Xenopus*, *Pipa*, and *Hymenochirus*," by C. G. S. DE VILLIERS.

3. "Description of three new Species of Anoplura from South African Mammals," by G. A. H. BEDFORD.

4. "Note on Hyperorthogonants," by Sir THOMAS MUIR.

5. "A Preliminary Note on the Rhenoster Bush (*Elytropappus rhinocerotis*) and the Generation of the Seed," by M. R. LEVYNS.
6. "On some Defensive Reflexes," by WILLIAM ADAM JOLLY.
7. "Note on Overvoltage Problems," by E. NEWBERY.
8. "Some South African Crustacea," by K. H. BARNARD.
9. "A Method for the Study of Dissociation of Haemocyanin," by LANCELOT T. HOGBEN.
10. "The Theory of Hessians from 1883 to 1914," by Sir THOMAS MUIR.
11. "Note on some Features of part of the Orange River Valley," by S. H. HAUGHTON.
12. "Archaeology of the Vaal River Gravels," by A. J. H. GOODWIN.
13. "Studies in the Growth of Grapes, Part II. Relationship between Sugar and Acid in the Juice," by P. R. v. D. R. COPEMAN.
14. "The Exchange of Electricity between Thunder-storms and the Ground," by B. F. J. SCHONLAND.
15. "On the Herpetological Fauna of the Lobatsi-Linokana Area," by J. H. POWER.
16. "The Symmetry and Crystalline Structure of the Crystals Potassium, Ammonium, Rhubidium, and Caesium Sulphate," by A. OGG.
17. "Studies in the Growth of Grapes, Part III. The Effect of Environment upon the Growth Constants," by P. R. v. D. R. COPEMAN.
18. "The Behaviour of *Acacia melanoxylon* R. Br. ('Tasmanian Blackwood') in the Knysna Forests: An Ecological Study," by JOHN F. V. PHILLIPS.
19. "Some new Species of Curculionidae from South Africa and South-west Africa," by A. J. HESSE.
20. "Studies in the Growth of Grapes, Part IV. The Initial Changes in Acidity," by P. R. v. D. R. COPEMAN.
21. "The Dinosaur Beds of Lake Nyasa," by F. DIXEY.
22. "On some Reptilian Remains from the Dinosaur Beds of Lake Nyasa," by S. H. HAUGHTON.
23. "On a *Myosurus* from South Africa with some Notes on *Marsilia macrocarpa*," by D. THODAY and M. A. POCKOCK.
24. "Studies in the Growth of Grapes, Part V," by P. R. v. D. R. COPEMAN.
25. "The Dentition of a Bushman Tribe," by M. R. DRENNAN.
26. "The Osteology of a Bushman Tribe," by D. SLOME.
27. "Colour and Chemical Constitution, Part XXIII. The Pigments of Flowers," by JAMES MOIR.
28. "Some Observations on the Production of Excitement Pallor in Reptiles," by LANCELOT T. HOGBEN and LOUIS MIRVISH.
29. "Note on a Rorqual Buried on the Cape Flats," by E. L. GILL.

30. "The Structure and Life-history of the South African Lagarosi-
phons," by VINCENT A. WAGER.

31. "*Olea laurifolia* Lam. ('Ironwood') : An Introduction to its
Ecology," by J. F. V. PHILLIPS.

32. "A New Method of Aerial Surveying, Second Paper," by H. G.
FOURCADE.

33. "The Principal Point and Principal Distance in Photogrammetry,"
by H. G. FOURCADE.

34. "Studies in the Growth of Grapes, Part VI. The Acid-sugar
Ratio," by P. R. v. D. R. COPEMAN.

Vol. XIV, parts 2, 3, and 4, of the Society's Transactions have been
issued during the year.

The undermentioned were elected Fellows of the Society in 1927 :—
MATTHEW ROBERTSON DRENNAN, M.A., M.B., Ch.B., F.R.C.S.E. ; PETRUS
JOHANN DU TOIT, B.A., Ph.D., Dr.Med.Vet. ; HENRY GEORGES FOURCADE ;
THOMAS ROBERTSON SIM, D.Sc., F.L.S., F.R.H.S. ; and HENDRIK JOHANNES
VAN DER BIJL, M.A., Ph.D.

At the end of 1927 the number of Honorary Fellows was 1, Fellows 68,
Members 151.

The death, since the 1927 Anniversary Meeting, of Professor E. S. EDIE
is recorded with regret.

During the year one member resigned.

The names of two members were struck off the list in 1927.

The exchanges with the Library have been maintained during the year.

Four hundred volumes of periodicals have been bound during the year,
and a further four hundred are being prepared for the binder.

TREASURER'S ACCOUNT FOR THE YEAR ENDING DECEMBER 31, 1927.

REVENUE.		EXPENDITURE.	
	£ s. d.		£ s. d.
To Subscriptions collected for 1927 :—		By Publications :—	
Subscriptions collected for 1924	0 1 0	Cash Paid for Printing, etc.,	
" " " 1925	5 0 0	to Neill & Co.	850 0 0
" " " 1926	38 16 0	Cost of Bank Drafts	4 8 6
" " " 1927	286 16 0	Amount paid in 1926 for 1927	
" " " 1928	9 8 0	Accounts	200 0 0
" " collected in advance for 1927	4 10 0	Amount owing to Neill & Co.	
Outstanding Subscriptions at December		for Printing, etc., in 1927	158 18 10
31, 1927	57 18 0	Cost of Bank Draft	0 18 0
	402 9 0		1214 5 4
Less : Outstanding Subscriptions at		Less : Amount received in	
December 31, 1926, £64. 17s. ; Sub-		1926 for Printing for 1927 280 0 0	
scriptions collected in 1927 for 1928,		Amount taken out of sum	
£9. 8s.	74 5 0	set aside for reproduction	
" Life Subscription paid in 1927	328 4 0	of Bushman painting to	
" Entrance Fees	25 0 0	cover cost	60 0 0
" Government Grant, 1927-8	11 0 0	Grant by Research Grant	
" Interest received :—	300 0 0	Board for Printing	
On Fixed Deposit, £800, at Standard Bank		Paper by N. Pillans 96 0 0	
for one year at 4 per cent.	32 0 0	Less : Grant by Board	
On £408 New Union of South Africa 5 per		for 1928 Printing .. 96 0 0	320 0 0
cent. Stock	20 8 0		894 5 4
On Money in Savings Bank Department of		Less : Receipts for extra re-	
Standard Bank	13 8 1	prints of Papers .. 16 3 6	
" Sale of Publications in 1927	64 9 0	Less : Amount received in	
Plus : Amount due for Sales in 1927	7 13 11	1927 for 1926 accounts 4 16 9	
1927 account paid in 1926	1 0 0		11 6 9
	73 2 11		882 18 7
Less : 1926 account paid in 1927	7 7 4	" Compilation of International Catalogue of	
" Loss in year 1927	65 15 7	Scientific Papers	16 16 0
	325 19 8	" Clerical Assistance and Work in Library ..	68 0 0
		" Local Printing and Stationery	42 19 6
		" Postages and Petties	16 9 3
		" Binding	85 19 3
		" Bank Charges for Commissions, Ledger	
		Fees, Fixed Deposit Stamps, etc. ..	3 4 3
		Less : Commissions paid by Members ..	2 7 3
		" Hire of Rooms and Caretaker	0 17 0
		" Insurance of Library in Cape Town and	6 6 0
		back Numbers with Neill & Co.	1 9 9
			£1121 15 4

ASSETS AND LIABILITIES AS AT DECEMBER 31, 1927

ASSETS.*		LIABILITIES.	
	£ s. d.		£ s. d.
Money at Standard Bank on Fixed Deposit for one year at 4½ per cent.	600 0 0	Subscriptions received in 1926, £1, and 1927, £9 8s., for 1928	10 8 0
Money in Savings Bank Department of Standard Bank	369 7 10	Printing Account for 1927 due to Neill & Co., and cost of draft	153 16 10
Balance at Standard Bank as per Pass Book	51 10 9	Received in 1927 for Printing in 1928	96 0 0
Union of South Africa £408 5s. per cent. Stock, 1929/39, reckoned at purchase price	400 0 0	Earmarked for Anthropological Periodicals (Council: Nov. 2, 1927), balance of amount set aside for reproduction of Bushman Painting, a sum not exceeding	290 0 0
Arrears of Subscriptions, as in Statement for 1926, £64 17s.; less £43 17s. paid off in 1927 and £5 struck off as irrecoverable	16 0 0	Excess of Assets over Liabilities:—	
Arrears of Subscriptions for 1927	41 18 0	Amount at December 31, 1926	£1256 5 4
Amount due for Sale of Publications	7 13 11	Deduct Loss in 1927	325 19 8
	<u>£1486 10 6</u>		<u>930 5 8</u>
			<u>£1486 10 6</u>

* Exclusive of value of Library and Publications of the Society held in Stock.

ENTRANCE FEES AND LIFE SUBSCRIPTIONS FUND.

	£ s. d.		£ s. d.
Amount of Fund at January 1, 1927	364 0 0	Amount of Fund at December 31, 1927	400 0 0
Life Subscription received in 1927	25 0 0		
Entrance Fees received in 1927	11 0 0		
	<u>£400 0 0</u>		<u>£400 0 0</u>

We hereby certify that we have examined the above accounts of Revenue and Expenditure, and of Assets and Liabilities, with the books, vouchers, and other documents and securities relating thereto, and that in our opinion these accounts set forth a correct statement of the affairs of the Society.

February 17, 1928.

WILLIAM FLINT,
LOUIS P. BOSMAN.

An Ordinary Meeting of the Society was held on Wednesday, April 18, 1928, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. W. A. JOLLY, was in the Chair.

Business :—

The Minutes of the Anniversary Meeting and of the Ordinary Meeting held on March 21, 1928, were approved.

Owing to the unavoidable absence of Professor NEWBERRY his motion for the formation of a Meteorological Society was postponed until next meeting.

Communications :—

"On some New Species of Bacteria Isolated from *Xenopus laevis*," by TH. SCHRIRE.

Three new organisms have been described and named. These have been isolated from a mould-like growth on a frog (*Xenopus laevis*).

The disease could not be reproduced by inoculation with various methods, but a mixed infection with all three organisms is highly pathogenic to frogs.

"*Curtisia faginea* Ait. ('Assegaai') : An Ecological Study," by J. F. V. PHILLIPS, D.Sc.

Curtisia faginea Ait. ("Assegaai"), an important tree sylviculturally and economically, is generally described as to distribution, habit, community, and habital relations. The principal features in the biology of the flowers, fruits, and young regeneration are outlined. Some data *re* growth are given, together with an account of the principal factors of mortality.

Curtisia is best developed in the Knysna forests, although it ranges from the Cape Peninsula to the forests of Gazaland. It is very rarely a dominant, and still more occurs in pure communities.

It is most at home in the medium moist forest at Knysna, while its regeneration stages can experience deep shade without dying; these develop very much better when provided with fairly strong light. In pole and later stages the species is definitely *semi-light demanding*.

The plant flowers regularly, fruits fairly regularly and heavily. The fruits are of moderate fertility; they are dispersed principally by the "Locrie" and the "Bush-dove," but the greater number aggregate at the base of the parent.

The rate of growth in girth is slow, but compares favourably with that shown by other Spp. of the Knysna forests, *e.g.*, *Olea laurifolia*, *Gonioma Kamassi*.

An Eriophyid forms galls upon the inflorescence, these galls often resulting in the loss of a large portion of the fruit-crop.

"Materials for a Revision of Crassulaceae" (the South African species of the genus *Crassula* L. emend. Schonl.), by S. SCHONLAND.

The author has studied a large number of South African species, both in the field and through living specimens in the laboratory. He has also examined almost all dried specimens of the genus preserved in herbaria of South Africa, Kew, British Museum, Oxford, Paris, and Berlin. He had the advantage of studying many of the eighteenth-century herbaria, notably those of Dillenius, Linnaeus, Plukenet, Lamarck, Thunberg, Jacquin, and Willdenow, and these have greatly helped him to make a considerable advance in clearing up the very complicated synonymy. He has also described a number of new species. In the introduction a brief history of the genus is given, and then the considerations are pointed out which have led to the formation of natural sections and groups in the genus. The phylogeny of the genus as it presents itself to the author is expressed in a table of sections and groups. This is followed by short descriptions of these sections and groups with their geographical distribution and keys to the species. Then follows an enumeration of the species with full literary references, enumeration of specimens examined, and occasional remarks, new species being placed in their order with those previously known.

Although the author takes rather a wider view of specific limits than most botanists, yet he recognises no less than 219 species of *Crassula* in South Africa. A full index is appended to the paper.

"A New Method of Aerial Surveying: Note on the Determination of the Verticals of a Plate Pair," by H. G. FOURCADE.

This note supplies a necessary step in a proof given in a former paper.

"On a Terrestrial Isoetes (*I. stellenbossiensis*, A. Duthie), from the Stellenbosch Flats," by A. V. DUTHIE.

This is the third species of Isoetes to be described from the Union of South Africa. It occurs in shallow depressions, which are damp in the winter but dry during the summer months, and has been found growing beside xerophytic plants, such as *Crassula undulata* and *Aristea cyanea*. The specific characters are well marked. The leaf bases persist as imbricate scales—those which protect the growing point being three-cusped. The narrow foliage leaves have poorly developed air spaces and three well-marked bundles of strengthening fibres. The sporangia lack a veil. The megaspores are reticulate and greenish-grey in colour, while the microspores are brown and spinulose.

"Veld-burning Experiments at Ida's Valley, Stellenbosch," by MARGARET R. LEVYNS.

The experiments, which are still in progress, were initiated in December

1924. The type of vegetation covering the area is that known as rhenoster-veld, which is shown not to be a stable type of plant community. Evidence is brought forward to prove that it must be a stage, although probably a protracted stage, in succession.

Burning leads to rapid increase of the rhenoster bush and certain other plants. Burning also induces vigorous growth among the petaloid monocotyledons and some other plants, this vigour being of a temporary nature.

Clearing the ground of bush does not favour the spread of the rhenoster bush. In this case vigorous growth is more apparent among the grasses than among the petaloid monocotyledons.

The effect of various conditions on the germination and growth of the more important constituents of the vegetation is described.

Determinations of soil moisture, specific acidity, and soil temperature are given.

The attention of members of the Royal Society of South Africa is directed to the Notice in the Government Gazette of the 20th April of the award of two Scholarships for the study abroad of Industries based on the utilisation of raw products existing in South Africa.

Applications for Grants-in-Aid of Research to be conducted during the current year are now invited.

Applications for Scholarships and for Grants-in-Aid of Research must be in the possession of the Secretary of the Research Grant Board by Thursday, May 17, 1928.

A. OGG,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, May 16, 1928, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. W. A. JOLLY, was in the Chair.

Business :—

The Minutes of the Ordinary Meeting held on April 18, 1928, were approved.

Professor NEWBERRY's motion: "That a Committee of this Society be appointed to consider the formation of a Meteorological Society for the Union" was referred to the Council for consideration.

In terms of Statutes, Chapters I, IV, the names of the Candidates for Fellowship in 1928 were read as follows :—

LANCELOT THOMAS HOGBEN, D.Sc.

Sir SPENCER LISTER, M.R.C.S., L.R.C.P.

HUGH ADAM REYBURN, M.A., D.Phil.

Communications :—

"The Influence of *Usnea* sp. (near *Barbata*, Fr.) upon the Supporting Tree," by JOHN F. V. PHILLIPS, D.Sc.

Research, employing anatomical study, infection experiments, transpiration experiments, instrumental measurements of the prime aerial and epaphic factors under consideration, and general observation has been carried out at the Research Station, Deepwalls, Knysna, into the relationship between *Usnea* and the *Podocarps*.

It is concluded that the lichen is definitely detrimental, in that its fungal component is parasitic upon the tissues external to (and sometimes internal to) the cork-cambium. Vigorous crowns may be infected as well as defective ones. The lichen cannot develop luxuriantly under the conditions of light, temperature, and humidity holding in undisturbed high forest, but grows apace when these factors are suddenly and severely altered by heavy exploitation. Preservation of the forest canopy in primeval forest would seem to be the very best means of inhibiting the rampant development of the lichen.

"The Action of Ammonia on Germanium Tetrachloride—Germanium Imide," by JOHN SMEATH THOMAS.

It has previously been shown (Thomas and Pugh) that ammonia reacts vigorously with germanium chloride, either in the state of vapour or in ethereal solution, giving a white substance, having a composition expressed by the formula $\text{GeCl}_4\text{6NH}_3$. This substance appears homogeneous when examined under the microscope and has an extremely small dissociation pressure at the ordinary temperature. When treated with ammonia under pressure, a compound having the formula $\text{GeCl}_4\text{16NH}_3$ is produced, the dissociation pressure of which is 1040 mm. at 0°C .

Ammonium chloride when treated with ammonia under pressure gives a compound $\text{NH}_4\text{Cl3NH}_3$, the vapour-pressure of which is 1040 mm. at 0°C ., and the possibility that the substance mentioned above may really be a mixture of $\text{Ge}(\text{NH})_2$ with $4\text{NH}_4\text{Cl}$ had therefore to be considered.

Attempts were made to separate germanium imide from this mixture by the use of suitable solvents. Methyl alcohol dissolves ammonium chloride fairly readily, and on treatment with this solvent the solution was found to contain ammonium chloride and to be practically free from germanium. The solid residue, however, was not pure germanium imide, but always contained products of the alcoholysis of this substance. In

the case of ethyl alcohol the solubility of ammonium chloride is smaller and the alcoholysis was found to be more marked.

Experiments were therefore made in which $\text{GeCl}_4\cdot 6\text{NH}_3$ was washed with liquid ammonia, which dissolves ammonium chloride readily. The solid residue was found to be extremely sensitive to traces of moisture, but eventually an apparatus was constructed in which the preparation of the GeCl_4 , treatment with ammonia, the subsequent washing with liquid ammonia, drying, and the weighing of the solid residue for analysis could be carried out without at any period opening the vessel to the air. In this way a product was obtained the analysis of which corresponded to 99.2 per cent. $\text{Ge}(\text{NH})_2$, and this result was considered, in view of the experimental difficulties, to be satisfactory.

This compound is a white powder which reacts very violently with water and which combines directly with hydrogen chloride, forming the imide hydrochloride. Substituted imides have also been prepared.

The construction of $\text{GeCl}_4\cdot 16\text{NH}_3$ in the light of the Lewis Langmuir and the Werner theories of values was briefly discussed.

"Compounds of Germanium Tetrachloride with certain Amines: (1) Compounds with Aniline," by W. W. SOUTHWOOD, M.Sc. (communicated by Professor J. SMEATH THOMAS).

When germanium tetrachloride was distilled into excess of aniline, and after reaction the excess of aniline removed by heating and evacuation, the product obtained had the empirical formula $\text{GeCl}_4\cdot 4\text{C}_6\text{H}_5\text{NH}_2$. The same product was obtained when excess GeCl_4 was distilled into aniline, and excess GeCl_4 removed by a current of dry air. There was no evidence of the formation of a product containing six molecules of aniline and analogous to the ammonia derivative. The product $\text{GeCl}_4\cdot 4\text{C}_6\text{H}_5\text{NH}_2$ may be a mixture, but no separation could be effected by sublimation under reduced pressure, as the whole solid sublimed unchanged. When, however, excess GeCl_4 was distilled into aniline dissolved in ether, a white precipitate of aniline hydrochloride was obtained and the solid left after evaporation of ether of filtrate was found to have the formula $\text{Ge}(\text{NC}_6\text{H}_5\text{HCl})_2$. That this product had symmetrical formula was evident, for analysis summed to 100 per cent. when all nitrogen was determined as aniline.

The product formed by GeCl_4 and aniline was therefore a mixture of aniline hydrochloride, and the substituted di-imide hydrochloride $\text{HCl}\cdot \text{C}_6\text{H}_5\text{N}=\text{Ge}=\text{NC}_6\text{H}_5\text{HCl}$.

Owing to the weakly basic nature of the aniline, there was no further action between the substituted di-imide hydrochloride and aniline to produce the free substituted di-imide.

(2) "Compounds with Ethylamine."

When excess ethylamine was distilled into GeCl_4 vigorous reaction at

first took place, with formation of a white solid. This white solid with excess of amine formed a translucent product. The excess amine was removed by dry air and the residue on analysis was found to be $\text{GeCl}_4\text{C}_2\text{H}_5\text{NH}_2$.

When excess amine was distilled into an ethereal solution of GeCl_4 a white precipitate was formed immediately. After the completion of the reaction the precipitate was filtered off, washed, and dried, and proved to be pure aniline hydrochloride. The filtrate on evaporation of the ether and excess amine was found to contain the free substituted di-imide $\text{Ge}(\text{NC}_2\text{H}_5)_2$.

That the product had the symmetrical structure was evident from the products of its hydrolysis which contained no ammonia and no secondary amine.

Here the strong base ethylamine displaces free substituted di-imide from its salt.

The compound containing six molecules of amine was found to have a high dissociation pressure. This was found to be about 370 mm. of mercury at 23°C . On pumping off ammonia from the compound until pressure was zero, a product analogous to the aniline derivative and containing four molecules of amine was obtained. This product was washed with ether and filtered. The precipitate was found to be ethylamine hydrochloride, and the filtrate on evaporation was found to contain the substituted di-imide hydrochloride.

"Colour and Chemical Constitution, Part XXIV.: A Complete Investigation of the Triphenylcarbinol or 'Aniline' Dyes," by JAMES MOIR.

This is the completion of Parts X., XIII., and XVI., obtained by making and examining all the remaining possible benzhydrol and triphenylcarbinol dyes. There are twenty-three possible dyes, and these possess in all seventy-five absorption bands in solutions of differing reaction (pH). The author puts forward a theory and method of calculation from chemical constitution whereby nearly seventy of the bands are explained.

"The Spermatogenesis of *Holopterna alata*," by Letitia Starke (communicated by Professor L. T. HOGBEN).

An account of the reduction of the chromosomes and the origin of the mitosome and middlesheath of the sperm in *Holopterna* is described. The somatic number of chromosomes is twenty, the reduced number ten. There is slight heteromorphism, but an XY pair is not recognisable. As in other Hemiptera, there is a diffuse stage intercalated in the heterotype prophase.

A. OGG,

Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, June 20, 1928, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. W. A. JOLLY, was in the Chair.

Business :—

The Minutes of the Ordinary Meeting, held on June 20, 1928, were approved.

Mr. U. REINECKE, L.D.S., was nominated for Membership; proposed by the Hon. Treasurer, seconded by Dr. J. SMEATH THOMAS.

The proposal of the Council to elect the Rt. Hon. Sir JAMES ROSE-INNES, P.C., K.C., K.C.M.G., to Fellowship, under Statutes, Chapter I., XIII., was read.

It was decided to recommend to the Council the holding of the Meetings in the afternoon instead of in the evening.

Communications :—

"The Breeding Habits and Life-history of some Transvaal Amphibia," by VINCENT A. WAGER.

The hitherto unrecorded life-history and breeding habits of *Hemismus marmoratum* are described. The frogs were found at Gravelotte, in North-Eastern Transvaal, the most southern record at present known. The eggs are laid in small cavities under the surface of the bank of a pool and are looked after by the female until they are hatched. The female then digs a tunnel from the nest to the water, down which the young tadpoles wriggle in a mass. The young tadpoles have a peculiar method of respiration by means of blood vessels in close proximity to the skin on the under side of the body—no external gills being present. They are able to remain alive out of the water for as much as eighteen days. The later stages of the tadpoles are described in detail.

Also brief notes are given on *Phrynomerus bifasciatus* and on *Hyperolius marmoratus*.

"Notes on the Habits and Life-histories of some Cape Peninsula Anura," by J. H. POWER and W. ROSE.

The breeding habits and life-histories of *Hyperolius horstockii* and *Arthroleptella lightfootii* are described. Nothing has been previously known of the life-histories of either the genus *Hyperolius* or *Arthroleptella*.

The metamorphosis of the small mountain toad, *Bufo rosei*, is also given.

"The Toxicity of the Fruit of *Melia azedarach* (Syringa Berries)," by D. G. STEYN and M. RINDL.

Melia azedarach, a tree native to the Himalayan region, is widely planted as an ornamental tree. It is known in South Africa as Bessiboom,

Sering, or Syringa, and the drupes, known in this country as Syringa berries, are commonly believed to be toxic. The recorded information with regard to their toxicity, obtained from American, Australian, and South African sources, is conflicting. In view of the inconclusive nature of the recorded evidence it seemed desirable to reinvestigate the problem, both from the toxicological and chemical point of view. The following is a summary of the results :—

1. Hogs, sheep, goats, rabbits, and guinea-pigs are susceptible to the syringa toxin, pigs being the most susceptible animals, and goats less so than sheep.

2. Muscovy-ducks were not killed even by relatively high doses of the plant material. Dogs vomited immediately after being drenched, and although they showed symptoms of poisoning they recovered after a period of several hours.

3. The symptoms produced in the fatal cases are paralysis and narcosis. Death usually occurs through suffocation. Irritation of the gastrointestinal tract is also evident, even when the administration is subcutaneous.

4. The toxin is thermostable.

5. Cold alcohol completely removes the toxin from the ground fruit, but the product is contaminated with considerable quantities of innocuous resin. By continuous hot percolation with ether, followed by chloroform, the poisonous principles can be extracted in a purer form.

6. Although the ether and chloroform extracts do not give rise to markedly different symptoms when injected into guinea-pigs and rabbits, the fact that continuous extraction with ether fails to completely remove the toxin makes the existence of at least two different principles probable. In this connection it should be pointed out that guinea-pigs and rabbits very often show the same train of symptoms when dosed and injected with extracts of different plants. These animals appear to be useless in the differential diagnosis of most plant poisons.

7. The toxins are not of the nature of alkaloids, toxalbumins, or glucosides easily hydrolysed by acids. They most probably belong to that indefinite group known as "bitter principles."

8. Attempts to obtain homogeneous products have so far proved abortive.

9. The addition of tannic acid to doses not exceeding fifteen grams has an inhibitory effect.

The investigation is being continued.

"Mean Sea-level and other Tidal Phenomena in Table Bay," by JAN DOMMISSE, Ph.D.

The paper is a brief summary of work on—(1) Mean sea-level at Cape
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Town, (2) Correlation between mean sea-level and barometric pressure, (3) Nineteen yearly tide, (4) Special tidal phenomenon in February 1907, and (5) Tide constants.

"The Resistance of *Limnaeidae* to Varying Degrees of Desiccation," by F. G. Cawston, M.D. (Cantab.).

The periodical drying of pools results in the death of those examples of the *Limnaeidae* which are stranded on the surface, as they are unprotected by an operculated shell; those that settle down into the mud are not affected by dry winds or the strong sun's rays, though they are still subject to the attacks of some of their natural enemies.

Physopsis and *Bulinus* are better able than *Limnaea* to hibernate in mud, because of the protection afforded by their stouter shell and smaller aperture. The truncate columella of *Physopsis africana* (Krauss) may also favour prolonged desiccation, as would the fact that *Physopsis globosa* (Morelet) is usually perforate.

With appropriate food *Planorbis pfeifferi* (Krauss), *Bulinus tropica* (Krauss), and *Melanoides tuberculatus* (Müller) have survived burying in garden soil for twelve days at a time, though all the *Limnaeae* were dead. *Limnaeae* prefer the light to darkness, and readily crawl out of water that is unfavourable; so that they resist the poison of *Tephrosia* better than the other species referred to.

The extensive growth of *Eichcornia crassipes* (Ponteder) rapidly dries up a pool infested with *Limnaeidae*, and *Tephrosia* might be used to destroy fluke-infested species.

"Preliminary Communication on the Chromatic Function in *Xenopus laevis*," by DAVID SLOME and LANCELOT HOGGEN.

The power of chromatic response is well developed in *Xenopus laevis*. Between 15° and 30° C. photic stimuli are the main agencies contributing to pigmentary effector activity. A statistical method of describing the extent of expansion or contraction of the dermal melanophores by assigning arbitrary numerical symbols was applied to the comparison of series of animals kept at different intensities of illumination with the field of vision defined by surfaces of different absorptive power. The results show—(a) that there is a slight degree of primary reactivity independent of the eyes, tending to greater expansion with greater illumination; (b) that there is a secondary and independent response for which the eyes are the receptor organs; (c) that the secondary response by contraction in a light-scattering and expansion to a light-absorbing surface is of much greater extent and requires a lower intensity of illumination than the primary response; (d) that the melanophores of eyeless toads or of normal toads kept for some time in darkness are intermediate in condition. It is evident that the photic responses of *Xenopus* cannot simply be explained by activation and

inhibition of pituitary activity by one set of visual afferent neurones. Either the afferent side of the mechanism of co-ordination or the efferent part must be two-fold in character.

A. OGG,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, July 18, 1928, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. W. A. JOLLY, was in the Chair.

Business :—

The Minutes of the Ordinary Meeting, held on June 20, 1928, were approved.

Mr. H. G. FOURCADE was admitted to Fellowship.

The Rt. Hon. Sir JAMES ROSE-INNES, P.C., K.C., K.C.M.G., was elected to Fellowship.

Mr. U. REINECKE was not elected to Membership.

Mr. W. J. HALL, Ph.D. (London), A.R.C.C., F.E.S., was nominated to Membership, proposed by the Hon. General Secretary, seconded by the Hon. General Treasurer.

The Council's selection of LANCELOT THOMAS HOGGEN, Sir SPENCER LISTER, and HUGH ADAM REYBURN for Fellowship was read.

The Secretary announced that the Council had accepted the recommendation of last Meeting, and proposed to hold the August, September, and October Meetings at 4.30 p.m.

The Council's decision to hold a joint *Conversazione* with the Cape Western Branch of the Medical Association of South Africa (B.M.A.) was announced.

Communications :—

"A Note on the Skin Secretion of *Xenopus laevis*," by J. W. C. GUNN.

The South African Clawed Toad, *Xenopus laevis*, when irritated by mechanical, electrical, or chemical stimuli applied to the skin, on the inhalation of irritating gases, or after the injection of certain drugs, secretes a white viscous fluid from its skin. This consists mainly of albuminous material, but contains substances which are pharmacologically active and toxic to mammalia. A specimen of dried secretion has remained active for six years.

One of the active substances has sympatho-mimetic reactions similar

to adrenaline. It produces a rise of blood-pressure, constriction of the blood-vessels, and acceleration of the heart with augmentation of its beat. The blood-pressure effect is reversed after a previous injection of a sufficient dose of ergotoxine. Larger doses lead to fibrillation of the ventricle. The movements of the uterus (isolated and *in situ*) of the rabbit and pregnant cat are stimulated, and of the non-pregnant cat and guinea-pig inhibited. The intestine is inhibited. Subcutaneous injection into the chameleon produces contraction of the melanophores.

The secretion does not give the chemical reactions of adrenaline. A dose of 10 mgs. of the crude secretion per kilogramme of body-weight is sufficient to produce a very marked rise of blood-pressure.

In some cases there is a slight fall of blood-pressure and slowing of the heart before the effects of sympathetic stimulation become noticeable. On the isolated mammalian heart in a few instances there was a stage of complete inhibition lasting for five to twenty seconds. The heart then began to beat again and rapidly showed a typical adrenaline effect. These effects are very similar to those of nicotine. *Xenopus* skin secretion is, however, still active, and produces a rise of blood-pressure in an animal in which the ganglia have been completely paralysed with nicotine. The site of action is therefore peripheral to the ganglia. The fall in blood-pressure, slowing of the heart, and, in some cases, stimulation of the intestine, seem due to the presence of bodies having an action on muscle like histamine, or on the parasympathetic nerve endings like muscarine. Since the action of these substances varies considerably in degree, it is possible that some of the effects may be due to decomposition products. These points are being investigated. The possibility of the presence of a trace of some substance with a digitalis-like action has not been definitely excluded.

An extract from the entire skin has a similar action to that of the secretion.

"A Preliminary Note on the Pharmacological Action of *Homeria collina*," by J. W. C. GUNN and LOUIS MIRVISH.

Homeria collina vent, N.O. Iridaceae, is known in the Cape Province as the yellow tulip or geel tulp. A few specimens of this plant, sufficient to enable a preliminary investigation of its action to be made, were obtained from the National Botanic Gardens, Kirstenbosch.

The material was dried, powdered, and macerated in 70 per cent. alcohol for forty-eight hours. The resulting tincture was employed in the experiments. Immediately before use the alcohol was driven off and replaced by an equivalent amount of Ringer's solution.

Injection of the alcohol-free tincture into the ventral lymph-sac of the frog leads to arrest of the heart, the ventricle being in complete systole and the auricles engorged with blood.

Perfusion of the isolated heart of the frog and mammal produces an increase of systole and diastole. This is soon followed by slowing and diminished relaxation. These effects become progressively more pronounced until the heart finally ceases in a condition of systole. Extrasystoles and heart-block (partial and complete) were noted in certain experiments on the perfused cat's heart.

Intravenous injection produces a rise of blood-pressure in the cat and rabbit. This is due mainly to the cardiac action, but also to vascular constriction, as shown by diminution of the intestinal volume.

Fatal doses produce fibrillation of the ventricle and acute dilatation of the heart.

The isolated intestine and uterus is stimulated.

These actions are similar to those produced by the Digitalis group of drugs. The toxicity of *Homeria collina* on the frog is about one-fourth that at *Digitalis purpurea*.

Rindl has demonstrated a similar action in *Homeria pallida* (Trans. Roy. Soc. S. Afr., xi, p. 251, 1924).

"The Effect of Testicular Extracts on the Calcium Blood-level," by L. MIRVISH and L. P. BOSMAN.

Alcoholic extracts of testes when injected into rabbits do not reduce the level of the blood calcium when given in the same doses as the corresponding ovarian extracts. It is only when the dose given is increased to the extent equivalent to about 200 grams of fresh testicular substance that a drop in the blood calcium occurs. The nature and extent of the drop in typical cases are similar to that observed on injection of ovarian extract. The calcium-reducing principle could not be extracted from the crude alcoholic extracts with ether or acetone. It would appear that the same hormone that is present in the ovary is also present in the testis, but in lesser concentration.

"The Effect of Extracts of the Suprarenal Cortex on the Calcium Blood-level," by L. MIRVISH and L. P. BOSMAN.

Bovine suprarenals from which the medulla was removed were extracted with alcohol. The adrenaline was removed by precipitation with ammonia, and the alcoholic extracts were purified by extraction with ether and acetone as in the preparation of the ovarian extract. This extract, when injected into rabbits, reduced the blood calcium by about 30 per cent. The least amount that produced a positive result was equivalent to 25 grams of the fresh suprarenal cortex, which is the same as in the case of residual ovary and corpus luteum. The nature and extent of the drop were also similar to that produced by the ovarian extract.

A. OGG,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, August 15, 1928, at 4.30 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. W. A. JOLLY, was in the Chair.

Business :—

The Minutes of the Ordinary Meeting, held on July 18, were approved.

The Rt. Hon. Sir JAMES ROSE-INNES, P.C., K.C., K.C.M.G., was admitted to Fellowship.

Mr. W. J. HALL, Ph.D., was elected to Membership.

Dr. E. C. GREENFIELD was nominated for Membership, proposed by Professor W. CAMPBELL, seconded by Professor J. W. C. GUNN.

ALEXANDER ZOOND, M.Sc., was nominated for Membership, proposed by Professor L. HOGGEN, seconded by the Hon. General Secretary.

Communications :—

"Note on Briochi's Treatment of the Product of Two Sums of Eight Squares," by Sir THOMAS MUIR, F.R.S.

"On the Action Current Staircase in Skeletal Muscle," by W. A. JOLLY.

The staircase is a phenomenon which has aroused much interest and evoked considerable discussion since it was first described in skeletal muscle in 1875.

It is a familiar fact that the twitches of a muscle stimulated by a series of stimuli exhibit at first a progressive increase in size, and this is usually regarded as demonstrating that previous stimulation has an improving effect on the muscle's responsive power. There is, however, doubt as to how far the increasing size of the recorded contractions is to be attributed to physiological and how far to mechanical causes.

The present paper is concerned with the staircase obtained in the first few responses, when the action currents of the muscle are recorded as indicators of its activity. A progressive increase in size of the action currents in muscle has previously been shown to occur. (Samojloff, 1908; Brücke, 1908; Keith Lucas, 1910; Fulton, 1926; Singer, 1928.)

My records have been obtained from the Tibialis anticus and Gastrocnemius muscles of the pithed *Xenopus* (the S.A. clawed frog or toad) on indirect stimulation through the uncut, and also the severed, sciatic nerve by means of submaximal break induction shocks. The rates of stimulation employed are 15 and 20 per second.

The action currents are led to the string galvanometer from zinc steel needles inserted into the muscle, either after removing the skin over the muscle or through windows in the skin. A condenser of 10 mfd. capacity is inserted in the galvanometer circuit. Ninety-two records have been made.

In both *Tibialis anticus* and *Gastrocnemius* the first three or four responses of a series show a staircase increase. In one experiment a staircase was absent in the *gastrocnemius* response.

In association with the progressive increase of the electrical variations in the staircase there is found a diminution in the latent period of excitation. In *Xenopus A* the average duration of the latent period of the first response of *Tibialis* from four experiments is 5.2σ , of the second 4.6σ , a diminution of 0.6σ . In *Xenopus B* the values are—first response of *Tibialis* 4.7σ , second response 4.3σ , a diminution of 0.4σ ; first response of *Gastrocnemius* 4.1σ , second response 3.7σ , a diminution of 0.4σ . In the case where no staircase was visible in the *gastrocnemius* responses, no diminution of the latent period could be demonstrated.

In *Xenopus B* after the staircase phenomenon had been recorded in both muscles by stimulation of the uncut sciatic nerve, the nerve was severed in the thigh central to the stimulating electrodes which were left in place. The effect of thus establishing a cross-section in the neighbourhood of the point of stimulation, a procedure which is known to increase the nerve's irritability, is to abolish the staircase phenomenon. The first two or three responses are now larger than before nerve-section and equal in amplitude, and there is now no diminution in the latent period. The figures are, first response—latent period 4.1σ , second response 4.1σ .

An explanation which has been put forward for the production of the staircase in contractions, viz., that it is due to a slowing of the vital processes on successive response (Fröhlich, 1905; Adrian, 1920) is not applicable to the staircase of action currents, which do not show a progressive slowing of their course.

The neuro-muscular apparatus employed in the present investigation has the blood circulation maintained, but, being isolated from the central nervous system, is devoid of tone and must be regarded as damaged to some extent by dissection and removal of skin. There is a good deal of evidence in the literature that staircase phenomena in general are more commonly observed when the condition of the tissue is subnormal, and there is some indication in the present research that the staircase is more marked the more the preparation has suffered from operative interference.

The fact that the increase of irritability caused by nerve section abolishes the staircase suggests that we are dealing at first with a tissue of slightly depressed irritability, and that stimulation improves its condition and increases its responsiveness, so giving rise to the staircase. The shortening of the latent period is consistent with this.

The precise manner in which previous stimulation increases irritability is not yet known.

“Notes on Two Larvae of South African Diptera belonging to the

Families Leptidae and Asilidae," by Dr. E. O. ENGEL (Munich) (communicated by E. L. GILL).

Accounts are given, with text-figures, of the structure of the larva and pupa of *Lampromyia sericea*, Westwood, and *Hyperechia nigripennis*, Wied. The first is the larva of a Leptid fly of the subfamily Vermileoninae, a group represented also in southern Europe and the southern United States. The larvae of this group of flies are remarkable for their mode of life. They make conical pits in loose sandy soil, exactly like the pits of ant-lions, and serving in the same way for the capture of ants and other terrestrial insects. The examples described in this paper were sent to the author from Stellenbosch by Dr. H. Brauns, and having survived the journey were reared through their remaining stages to the adult fly. Their structure is described and figured, and is correlated with their actions, especially with the bent-spring action with which they throw up the sand to form their pits and to overwhelm their victims, and with the suctorial action whereby they extract the juices from their prey without making any perceptible puncture in the integument.

The family Asilidae (the Robber-flies), to which belongs *Hyperechia nigripennis*, the second form described by Dr. Engel, is specially richly represented in South Africa. Most of the Robber-flies are long-bodied and long-legged, and use their spiked hind legs in capturing other insects on the wing. But *Hyperechia* and other members of the subfamily Laphriinae are quite different in appearance; they bear a striking superficial resemblance to certain of the Carpenter Bees—in this case to *Xylocopa caffra*—and it is now known that their larvae are parasitic in the nests of the bees which they mimic. The *Hyperechia* larva and pupa are here described and figured; the larval mouth-parts are found to be much reduced, presumably in correspondence with the parasitic mode of life.

"The Effect of Temperature on the Blood Sugar Level and the Glucose Tolerance in *Xenopus laevis*," by LOUIS P. BOSMAN and H. ZWARENSTEIN.

The blood sugar levels at 5° C., 10°, 20°, 25°, are respectively 69, 57, 44.2, 37 mg. per 100 c.c.

1 c.c. of 2 per cent. solution of glucose (=20 mg.) was injected into the dorsal lymph sac. This is equivalent to the ingestion of 50 grm. glucose by a man weighing 70 kilos in carbohydrate tolerance tests. The blood sugar was then estimated at various intervals after injection.

The tolerance curve at 5° C. shows a maximum of 124 mg. 3 hours after injection, and turns to normal 4 hours later.

At 10° C.: max. of 119 mg. $\frac{1}{2}$ hour after injection, normal $5\frac{1}{2}$ hours later.

At 20° C.: max. of 173 mg. $\frac{1}{2}$ hour after injection, normal $6\frac{1}{2}$ hours later.

The corresponding figures for man are: normal blood sugar, 90 mg. per 100 c.c. Max. of 180 mg. $\frac{1}{2}$ hour after ingestion of 50 grm. glucose. Normal 1 hour later.

"An Account of a Pebble Industry in the Transvaal," by E. J. WAYLAND, A.R.C.Sc., F.G.S.

Various artefacts found at Belfast, in the Transvaal, are described. These seem to fall into two industrial groups. The first consists of a number of artificially chipped quartzite pebbles; the second has Mousterian affinities. These two industries are compared with the Kafuan and the Sangoan of Uganda respectively.

Relative age can be shown, the pebble industry being of earlier age than the Mousterian, but actual age cannot be judged for the material submitted from the Transvaal, while presumption of age based upon knowledge of the Uganda industries would be unsafe.

A. OGG,
Hon. General Secretary.

ANNUAL MEETING.

The Annual Meeting of the Society was held on Wednesday, September 26, 1928, at 4.30 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. W. A. JOLLY, was in the Chair.

Business:—

The following Candidates were elected Fellows of the Society:—
LANCELOT THOMAS HOGBEN, D.Sc.; Sir SPENCER LISTER, M.R.C.S.,
L.R.C.P.; HUGH ADAM REYBURN, M.A., D.Phil.

ORDINARY MEETING.

An Ordinary Meeting was held after the Annual Meeting.

The President was in the Chair.

Business:—

The Minutes of the Ordinary Meeting, held on August 15, 1928, were confirmed.

Dr. E. C. GREENFIELD and ALEXANDER ZOOND, M.Sc., were elected to Membership.

Communications :—

"Note on Sums of Equigrade Coaxial Minors," by SIR THOMAS MUIR, F.R.S.

"The Time Factor in Amphibian Colour Response," by DAVID SLOME and LANCELOT HOGBEN.

A statistical method for treating colour change in *Xenopus* quantitatively, as described in a previous communication, has been applied to the elucidation of the time relations of the "secondary" or co-ordinated aspect of the phenomenon. The time taken to reach equilibrium in passing from the dark and pale condition of the skin to the intermediate state in darkness, and *vice versa*, and the time taken for complete reversal from one to the other state under optimum conditions have been studied. The result of these experiments is to show that a separate mechanism of discharge is involved in the black background and white background responses. Removal of the whole pituitary gland abolishes the first, and removal of the anterior lobe alone abolishes the second type of response.

"Respiratory Exchange in the Fresh-water Crab," by ALEXANDER ZOOND and ENID HOGBEN.

The experiments recorded in this communication constitute the beginning of a series of investigations undertaken with a view to establishing experimental evidence for the function of the so-called organs of respiratory exchange in Invertebrates.

Preliminary experiments showed that the South African fresh-water crab, *Potamonautes*, is able to survive for more than seven days, both when immersed in deep running water and when completely deprived of water. The importance of the scaphognathite in the maintenance of respiratory exchange was indicated by the observation that animals from which the scaphognathites had been removed, died in 6-18 hours when immersed in deep water, but lived for several days in air.

Determinations of the dissolved oxygen consumption of normal and scaphognathectomised crabs were carried out by the Winkler method. The average consumption of oxygen for forty-three normal animals in water was found to be 42.3 mg. per kilo/hour, the S.D. of the mean being 2.4. The average for twenty-five scaphognathectomised animals was 3.5 mg. per kilo/hour, S.D.=0.56. The difference between these means is 38.8, S.D.=2.5.

The results show that normal respiration in water is only possible so long as water is kept circulating in the gill chamber by the rhythmic movement of the scaphognathite. It appears that the rate of diffusion of atmospheric oxygen is sufficiently rapid to render the ventilating activity of the scaphognathite superfluous. This conclusion will be tested experimentally.

"Colour and Chemical Constitution, Part XXV. A Quantized Phenomenon: the Halochromic Colours of the Doubly-linked Diphenylene Compounds," by JAMES MOIR.

About forty-two compounds are possible, made of two benzene rings and two ortho linkages. All of them, though nearly colourless in other solvents, give bright-coloured solutions in concentrated sulphuric acid. The author has made and examined thirty-six of them, and discovered a general law involving a single constant for the whole of the substances.

The paper also contains suggested quantum mathematics for the author's discovery of the relationship between absorption wave-length and distance between auxochromes.

The data of Part XXIV. are discussed anew.

A. OGG,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, October 17, 1928, at 4.30 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. W. A. JOLLY, was in the Chair.

Business :—

The Minutes of the Annual Meeting and of the Ordinary Meeting held on September 26, 1928, were confirmed.

LANCELOT THOMAS HOGBEN, D.Sc., and HUGH A. REYBURN, D.Phil., were admitted as Fellows of the Society.

CECIL GORDON, M.Sc., and DAVID SLOME, M.A., proposed by Professor HOGBEN, seconded by the Hon. General Secretary; and Dr. J. H. FERGUSON, proposed by Professor CAMPBELL, seconded by Professor GUNN, were nominated to Membership.

The recommendation of the Council that the meetings of the Society be held in the evenings in 1929 was adopted.

The Council's nominations of Officers and Members of Council for 1929 is as follows :—

President, Dr. W. A. JOLLY; Hon. Treasurer, Dr. L. CRAWFORD; Hon. Secretary, Dr. B. F. SCHONLAND; Hon. Librarian, Dr. J. SMEATH THOMAS; Members of Council, Dr. R. S. ADAMSON, Dr. C. W. MALLY, Dr. H. SPENCER JONES, Dr. C. F. JURITZ, Dr. A. OGG, Professor H. H. PAINE, Mr. C. M. STEWART, and Dr. R. B. YOUNG.

Communications :—

"Demonstration of the Magnetometer-Earth-Inductor made by the

Department of Terrestrial Magnetism of the Carnegie Institution of Washington and some Preliminary Results," by E. N. GRINDLEY.

The combined theodolite-magnetometer-earth-inductor made by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington was demonstrated.

Some maps were exhibited, on which were plotted the differences in declination, inclination, and horizontal intensity, between the results of the present survey, corrected to epoch July 1, 1928, and those of Beattie's survey, for epoch July 1, 1903, for some twenty stations in the region between Cape Town and Durban.

The change in declination in the twenty-five years ranges from a decrease of four degrees in westerly declination at Cape Town to a decrease of nearly six degrees in Natal. The inclination has increased in the southerly direction by amounts from two degrees at Durban to three and a half degrees at Cape Town. The horizontal intensity has decreased by $\cdot 02400$ c.g.s. units in Natal, and by more than $\cdot 02700$ units in the south-west regions of the Cape.

"An Empirical Formula for the Absorption-bands of Ammonia, Phosphine, and Arsine (Robertson and Fox) in the near Infra-red," by JAMES MOIR.

The formula is that of a fundamental wave-number multiplied by a vulgar fraction, the denominator of which depends on the gas: the result is modified by small corrections involving constants and integers.

"On some New Species of Organisms Isolated from *Xenopus laevis*," by TH. SCHRIRE and E. G. GREENFIELD.

Three new organisms have been isolated from a spontaneous abscess in a frog (*Xenopus laevis*).

One of these organisms has been shown to be of an Anthracoid nature, and is extremely pathogenic to frogs and guinea-pigs. No toxin could be isolated from this organism.

"The Susceptibility of the African Chameleon to Digitalis Bodies," by J. W. C. GUNN.

Great differences are found in the susceptibility of animals to drugs of the Digitalis series. Amongst cold-blooded animals, for instance, the grass-snake and the toad (*Bufo*) are tolerant of very much larger doses than the frog (*Rana*). The South African clawed toad (*Xenopus laevis*) is, on the other hand, susceptible to the same degree as *Rana*.

Experiments have been performed with various digitalis bodies on the African Chameleon to see if it has any natural tolerance to these substances.

Solutions of Strophanthin, and Tinctures of Digitalis, Squills, and Strophanthus, were tested on *Xenopus* and *Chameleo* at the same time. The strophanthin had been previously tested in England on *Rana temporaria*.

The injections were made into the ventral lymph sac of *Rana* and *Xenopus* and into the peritoneal cavity of *Chameleo*.

The symptoms seen in the chameleon are similar to those observed in the frog. The heart is slowed and finally stops, with the ventricle in complete systole and the auricles engorged. Pallor of the skin was noted in 40 per cent. of cases.

For comparison of susceptibility the doses required to stop the heart in an hour were calculated, and the results are given in the following table. The amounts are stated per gramme of body weight.

Preparation.	<i>Rana temporaria.</i>	<i>Xenopus laevis.</i>	<i>Chameleo pumulus.</i>
Strophanthin . . .	0.00008 mg.	0.000070 mg.	0.00007 mg.
Tincture Digitalis . . .	..	0.005 c.c.	0.005 c.c.
Tincture Scillae . . .	..	0.006 c.c.	0.0035 c.c.
Tincture Strophanthi . . .	..	0.000065 c.c.	0.000065 c.c.

From these figures it will be seen that the African Chameleon reacts to Digitalis bodies like the frog, and does not show any special tolerance like the grass-snake.

"The Excretion of Creatine in *Xenopus laevis*," by H. ZWARENSTEIN.

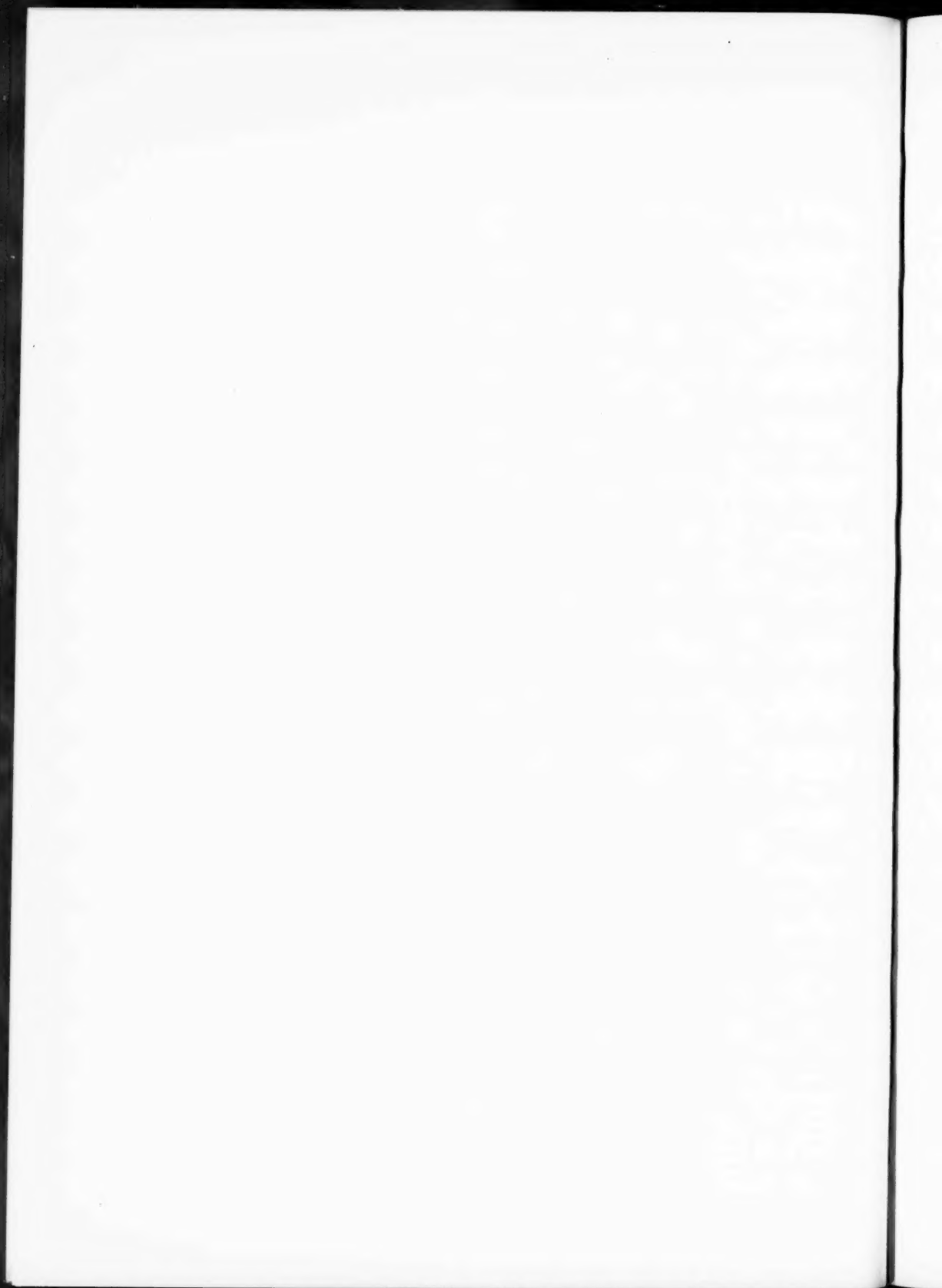
Previous attempts by various investigators to demonstrate the presence of either creatine or creatinine in frog's urine were entirely negative.

The urine of *Xenopus* was collected by keeping ten frogs in a glass receptacle for from one to five days. Pure urine was obtained by tying the skin around the anus and releasing the ligature every twenty-four hours. In both the pure and diluted urines the Jaffé test for creatinine was negative. On boiling the urines with picric acid and then adding 10 per cent. sodium hydroxide a definite and characteristic reddish orange or deep red colour developed. The above results indicate that *Xenopus* excretes creatine, but not creatinine.

The amount excreted is about .04 mg. by each frog in twenty-four hours. 100 c.c. of pure urine contains about 2 mg. creatine.

"Contributions to a Knowledge of the Transvaal Iridaceae," by N. E. BROWN (communicated by J. BURT DAVY).

A. OGG,
Hon. General Secretary.



LIST OF OFFICERS, FELLOWS, AND MEMBERS.

DECEMBER 31, 1928.

MEMBERS OF COUNCIL.

President.

W. A. JOLLY.

Vice-Presidents.

H. B. FANTHAM, C. F. JURITZ.

R. S. ADAMSON.

L. CRAWFORD, *Hon. Treasurer.*

A. L. DU TOIT.

H. B. FANTHAM.

J. W. C. GUNN.

S. H. HAUGHTON.

W. A. JOLLY.

C. F. JURITZ.

A. OGG, *Hon. Gen. Secretary.*

C. M. STEWART.

J. SMEATH THOMAS.

B. DE ST. J. VAN DER RIET.

FELLOWS.

Adamson, *Prof. R. S., B.Sc., M.A., University of Cape Town*

Barnard, K. H., *M.A., D.Sc., South African Museum, Cape Town.*

Beattie, *Sir Carruthers, D.Sc., LL.D., Principal, University of Cape Town.*

Bews, *Prof. J. W., M.A., D.Sc., Natal University College, Pietermaritzburg, Natal.*

Bohle, H., *M.I.E.E., Dr. Ing., University of Cape Town.*

Bolus, Mrs. F., *B.A., Bolus Herbarium, Kirstenbosch, Newlands, Cape Town.*

Brown, *Prof. A., M.A., B.Sc., F.R.S.E., University of Cape Town.*

Buchanan, *Hon. Sir John, Kt., Claremont, Cape Town.*

Burt-Davy, J., *Ph.D., F.L.S., F.R.G.S., Imperial Forestry Institute, Oxford, England.*

Campbell, *Prof. Wm., B.Sc., M.B., Ch.B., University of Cape Town Medical School,
Mowbray, Cape Town.*

Compton, *Prof. R. H., M.A.*, University of Cape Town.

Crawford, *Prof. L., M.A., D.Sc., F.R.S.E.*, University of Cape Town.

Dalton, *Prof. J. P., M.A., D.Sc.*, University of the Witwatersrand, Johannesburg.

Doidge, Miss Ethel M., *M.A., D.Sc., F.L.S.*, Division of Botany, P.O. Box 994, Pretoria.

Drennan, *Prof. M. R., M.A., M.B., Ch.B., F.R.C.S.E.*, University of Cape Town Medical School, Mowbray, Cape Town.

Duthie, Miss A. V., *M.A.*, University of Stellenbosch, Cape Province, South Africa.

Du Toit, A. L., *B.A., D.Sc.*, c/o De Beers Consolidated Mines, P.O. Box 616, Kimberley.

Du Toit, P. J., *B.A., Ph.D., Dr. Med. Vet.*, P.O. Box 593, Pretoria.

Fantham, *Prof. H. B., M.A., D.Sc.*, University of the Witwatersrand, Johannesburg.

Fourcade, H. G., Witte Els Bosch, Humansdorp, Cape Province, South Africa.

Goetz, *Rev. E., S.J., M.A., F.R.A.S.*, Bulawayo, Southern Rhodesia.

Green, H. H., *D.Sc., F.C.S.*, P.O. Box 593, Pretoria.

Gunn, *Prof. J. W. C., M.A., M.B., Ch.B.*, University of Cape Town Medical School, Mowbray, Cape Town.

Hall, A. L., *M.A., Sc.D.*, Geological Survey, P.O. Box 401, Pretoria.

Hamlin, E. J., *D.Sc.*, P.O. Box 7016, Johannesburg.

Haughton, S. H., *D.Sc.*, South African Museum, Cape Town.

Hewitt, J., *B.A.*, Albany Museum, Grahamstown, South Africa.

Hogben, *Prof. L. T., M.A., D.Sc., F.R.S.E.*, University of Cape Town.

Jolly, W. A., *M.B., Ch.B., D.Sc., LL.D.*, University of Cape Town Medical School, Mowbray, Cape Town.

Jones, H. Spencer, *M.A., D.Sc., F.R.A.S.*, Royal Observatory, Cape Town.

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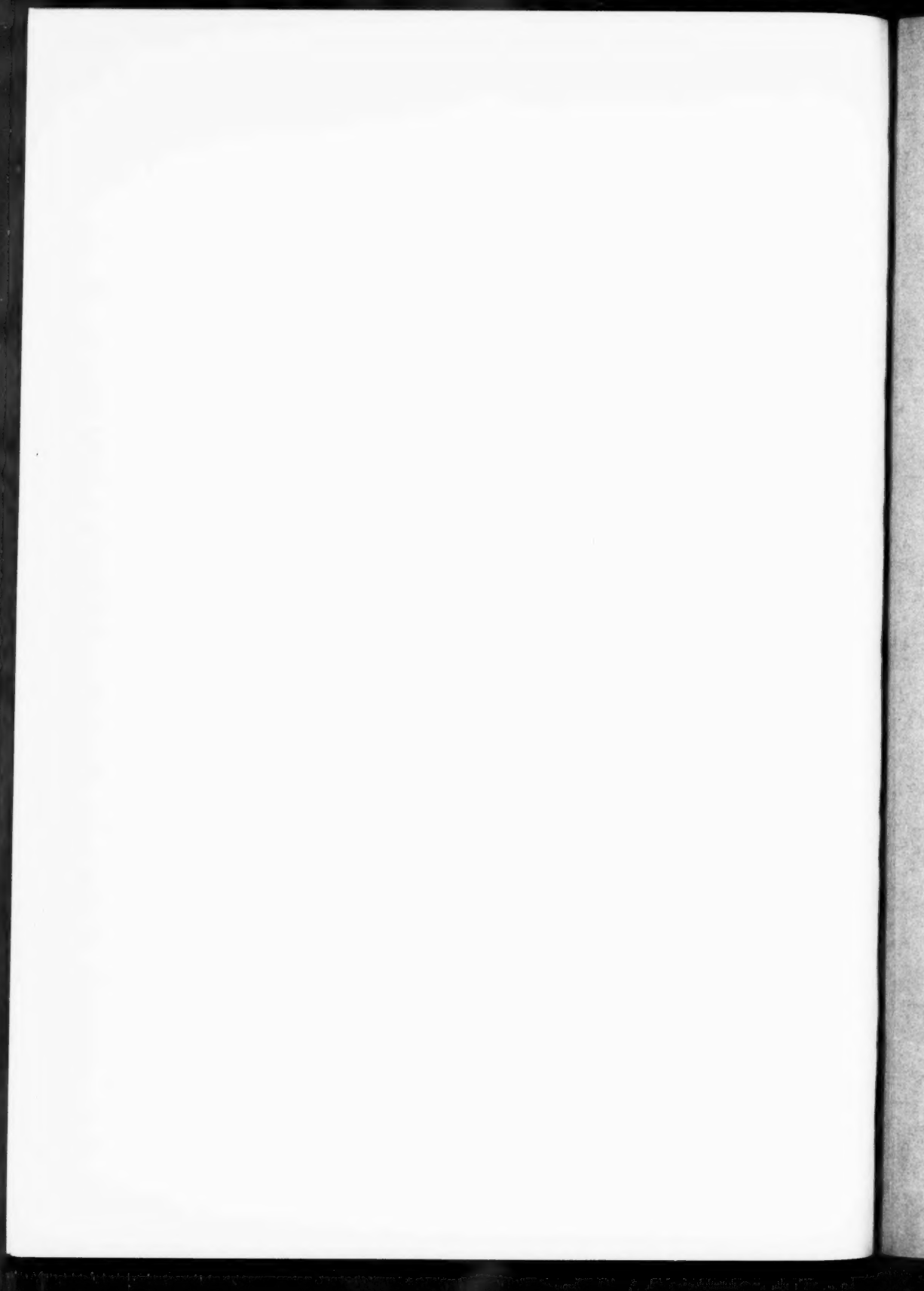
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